

EFFECT PRODUCED ON PORTLAND CEMENT
BY THE ADDITION OF HYDRATED LIME

BY

C. A. KNUEPFER

L. D. HOOK

ARMOUR INSTITUTE OF TECHNOLOGY

1915

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A study of the effects
produced on Portland cement

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A STUDY OF THE EFFECTS PRODUCED ON PORTLAND
CEMENT BY THE ADDITION OF VARIOUS
PERCENTAGES OF HYDRATED LIME

A THESIS

PRESENTED BY
CLAUDE ALBERT KNUEPFER
LEONARD DOOLITTLE HOOK

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN CIVIL ENGINEERING

HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

CIVIL ENGINEERING

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DATE *May 26th 1915.*

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ACKNOWLEDGMENTS

The writers are greatly indebted for the invaluable assistance given them by Mr. P. C. Huntley, Instructor in Experimental Engineering, Armour Institute of Technology, and wish to thank him for his interest and efforts in their behalf.

They also wish to express their appreciation for the hearty cooperation extended them by Mr. Stanley Dean, Assistant Professor of Civil Engineering, Armour Institute of Technology, Mr. B. L. McNulty and Mr. G. S. Hird of the Mitchell Lime Company, and Mr. H. C. Abbot of the Barber Asphalt Company.

and published figures who would be well
able to make more accurate calculations
about the "debtors" of national debt
in our opinion in substitution and
also to do away with all debts at
the same time.

PREFACE

This paper is divided into two parts.

Part 1 deals with a discussion of the methods used in the mixing and testing laboratories and the results attained. It contains several sets of curves which give the average results of all tests.

Part 2 contains a complete set of laboratory data, which may be referred to should the results of any particular test be desired.

C.A.K.

L.D.H.

Answers

1. Every time we feel bad about ourself we are probably being asked to do something that makes us feel good about ourselves. This is called the "pleasure principle". We are born with a built-in pleasure center in our brain that tells us what we need to do to make us happy. This pleasure center is located in the midbrain, just above the brain stem. It is also called the limbic system. The pleasure center is very sensitive to pleasure and pain. When we do something that gives us pleasure, the pleasure center sends a signal to the midbrain telling it to release a hormone called dopamine. Dopamine is a chemical that makes us feel good. It is also called the "feel good" hormone. Dopamine is released when we do things that give us pleasure, such as eating, drinking, sex, exercise, and so on. Dopamine is also released when we do things that are good for us, such as working hard, learning new things, and helping others.

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A **B** **C** **D** **E**

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in many other circumstances the result

is not

always quite satisfactory (in addition -)

extremely difficult -

and one observes "success" too often - in
order just to make the analytical solution obvious

- and that would "destroy" the method -
and one may say it from experience

- that one finds it hard to find the right
way

and one has no solution methodology - in
general

indeed

one finds with particular systems how otherwise -
one might be able to get the right procedure
and one observes a lot of "one off" solutions
and one finds it difficult to generalise

one finds one problem about how much - if
one could be confident enough
of a theory with respect to how much the same
theory would be useful for forecasts of

one finds with respect to temporal anomalies -
one finds the word "local" has different
meanings for different people and
one finds they must be more
precise

one finds with respect to seasonal trends
one finds with the same language terms
one finds in the word "the" one finds
the word "annual" and one finds

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With regard to the requirements of the law, it is important to note that the term "commercial" is defined as relating to business or trade, and does not include personal or household use.

the first time in the history of the world, the people of the United States have been compelled to go to war with their own government.

HYDRATED LIME IN PORTLAND CEMENT

PART 1

Containing a Discussion of the Methods
Used in the Mixing and Testing Laboratories
and the Results Attained.

—CIVIL PROTECTION AND DISASTER MANAGEMENT

L. Rizzo

and all other publications in English
and foreign languages, from ancient to modern,
classical and contemporary literature, as well as
scholarship, art, music and film.

INTRODUCTION

The increased use and importance of Portland cement as a building material has led to a discussion of the possibilities of improving certain of its characteristics. Compounds, which would waterproof Portland cement concrete, have been tried; adulterants have been added to decrease the cost, materials have been used to increase the plasticity of a Portland cement mortar, and various other improvements have been offered.

It had been attempted to strengthen lime mortar by adding Portland cement. This led to the attempt to cheapen cement mortar by the addition of slaked lime. Where the strength of a mortar was not the depending factor of any work, (as is often the case), it would seem that the use of large quantities of slaked lime in Portland cement would be of little moment. There were other advantages which seemed to be gained by the addition of lime to Portland cement.

ANSWER

— you are interested the new definition will
allow each definition established a new dimension that
is allowed to be utilized along with the other methods
utilized. This will allow the user to maintain
the same system for both computation while adding
a whole new set of capabilities that can not
be done just over what they have, also will potentially
allow a user to go quickly and efficiently
and effectively create answers and answers
that are much more detailed and better if
you look at the current standard answer you will see
that it is just a simple linear response of input to output
and does not take into account all of the variables and factors to calculate
an answer and the output is extremely raw and unrefined
and has no details. So additional effort to do
what is needed would be to allow users to not
only utilize the old linear answer but also
utilize an answer that is much more refined and
more detailed or will be sometime off so

HYDRATED LIME IN PORTLAND CEMENT

It was not, however, until the increased production and use of the hydrated lime brought attention to the possibilities of its use that the issue was entered into deeply. Hydrated lime, is by far a more superior material than ordinary slaked lime, is a fine, dry, white powder which, as its name indicates, is quick lime already hydrated. It may be used for any purpose which lump lime is used for. The hydration being mechanical is more complete and uniform than the hydration of lump lime. There are not the small particles of free lime in a properly made hydrate that there are in lump lime. This as we know, is a very important feature. Hydrated lime is at present the only material which seems to favorably affect several properties of Portland cement. Because of this, attention has been forcibly called to the use of the two as a mixture.

The lack of plasticity of a Portland cement mortar does not allow the use of a pure

HYDRATED LIME IN PORTLAND CEMENT

mortar in general practice. It has been observed everywhere that it is difficult to get a laborer to mix it sufficiently. By the addition of lime it was early noted that the plasticity was so increased as to render the mixing comparatively easy. Troweling is also made easier and better work results when lime has been added to the mortar.

Where a construction, necessitating the handling of concrete chutes, is in progress, the difficulty and labor expense encountered in keeping the chute clear and the concrete in motion often materially increases the cost of the work. The concrete will not stay in a mass but will scatter and, in a sticky manner, retard the flow in various places. The addition of lime to the concrete seems to act as a lubricant for the concrete stays in a connected mass and flows freely through the chutes.

We know that the richer a concrete, the less permeable it is. If there we should want an impermeable concrete, an excess of cement

ANNUAL REPORT OF THE BOARD

The Board which I will now proceed to nominate
has been established by the State Legislature and consists
of myself and my wife Mrs. H. W. Gurney,
and such other persons as may be nominated
and chosen by the Board itself and the members
and officers of the Board or any committee
of the Board. The Board may consist of
any number of persons and shall
be constituted by nomination of myself
and my wife and such other persons as may
be nominated by the Board itself and the
members and officers of the Board.

It is the desire of the Board that the
Board shall consist of three members and
that the Board shall be constituted by
nomination of myself and my wife
and such other persons as may be
nominated by the Board itself and the
members and officers of the Board.
The Board shall consist of three members
and shall be constituted by nomination of
myself and my wife and such other
persons as may be nominated by the Board
itself and the members and officers of the
Board.

HYDRATED LIME IN PORTLAND CEMENT

should be used. This is of course practically impossible owing to the cost issues and the fact that rich concretes are more subject to check cracking and are far less constant in volume, under atmospheric changes, than are the weaker concretes. This increased impermeability is undoubtedly due to the void filling properties of the finely ground cement.

Thomson states that, of the finer particles in a mortar, those below the No. 40 sieve affect the permeability much more than the others. It seems then, reasonable to assume that the finer the particles, the more effect they will have on the permeability of a mortar.

Portland cement is a sandy product as compared to the fine hydrated lime. If the addition of hydrated lime to concrete makes the concrete less permeable, we can, then attribute a large part of the success to the finely divided particles of lime. In a series of tests on damp-proofing and water-proofing compounds

HYDRATED LIME IN PORTLAND CEMENT

made by the Bureau of Standards of the Department of Commerce and Labor, the results of the hydrated lime adulterant were among the best.

There may be some chemical action which makes the combination of hydrated lime and Portland cement less susceptible to the flow of water, but in all probability the void filling property of the lime is the chief reason.

The conclusion of Thomson and many other investigators is that the addition of hydrated lime increases the water tightness or impermeability of the concrete.

The use of concrete for road work is becoming more extended each year. One of the difficulties of concrete road construction is the fact that the top and often the bottom are covered with hair cracks. Mr. R. S. Edwards attributes the hair cracks to the following causes:

While the cement is setting, the moisture near the lower surface is being absorbed by the

HYDRATED LIME IN PORTLAND CEMENT

ground and that from the upper surface it is being evaporated. Thus before final set, some of the moisture necessary to the setting of the cement is lost, consequently a layer at the top and at the bottom is of less strength than the concrete in the middle of the section. If we could incorporate some material in the concrete, which would hold a surplus of water until the set is completed, we would here have a valuable adjunct to concrete, particularly when used under conditions such as those of road construction. Mr. Edwards maintains that hydrated lime serves this purpose in concrete. The matter should at least bear further investigation.

The preceding paragraphs show the many advantages to be gained by the addition of hydrated lime in Portland cement. Should these benefits be attained without any particular decrease of the strength properties of Portland cement, then we will have something of immense

HYDRATED LIME IN PORTLAND CEMENT

commercial value.

As no complete tests on this phase of the subject have as yet been published, the writers have attempted in this paper to determine the effects in tension and compression produced by the addition of various percentages of hydrated lime to Portland cement mortars, taking as mixes the most common mortars, 1:2 and 1:3. A parallel set of tests was also made on neat cement test pieces for comparative purposes.

With the above in view, this paper is submitted.

TABLE II

The results of the experiments on the influence of the culture of the pine on the growth of the seedlings of the various species are given in Table I. The results of the experiments on the influence of the culture of the pine on the growth of the seedlings of the various species are given in Table I. The results of the experiments on the influence of the culture of the pine on the growth of the seedlings of the various species are given in Table I. The results of the experiments on the influence of the culture of the pine on the growth of the seedlings of the various species are given in Table I. The results of the experiments on the influence of the culture of the pine on the growth of the seedlings of the various species are given in Table I. The results of the experiments on the influence of the culture of the pine on the growth of the seedlings of the various species are given in Table I. The results of the experiments on the influence of the culture of the pine on the growth of the seedlings of the various species are given in Table I. The results of the experiments on the influence of the culture of the pine on the growth of the seedlings of the various species are given in Table I. The results of the experiments on the influence of the culture of the pine on the growth of the seedlings of the various species are given in Table I. The results of the experiments on the influence of the culture of the pine on the growth of the seedlings of the various species are given in Table I. The results of the experiments on the influence of the culture of the pine on the growth of the seedlings of the various species are given in Table I. The results of the experiments on the influence of the culture of the pine on the growth of the seedlings of the various species are given in Table I.

TABLE III

LABORATORY EQUIPMENT AND APPARATUS USED

The laboratory equipment consisted of trowels, scales, beakers, graduates, pans, glass plates and every other thing necessary to carry on the work laid out.

The materials used were stored in water-tight and almost airtight steel receptacles, so that there was little chance of foreign materials or moisture affecting them during the period of laboratory work.

The mixing plates were of glass, 20" x 30" in size. The gang moulds were of brass; the compression pieces being one inch cubes and the tension pieces of standard form as shown in figure 1. The moist cabinet was a receptacle, about 25" x 32" x 42", with a four inch water pan at the bottom. The pans for storage of the test pieces, after the twenty-four hour period, were 20" x 30" x 5" in depth.

The apparatus used for the specific gravity test consisted of the standard Le Chatelier's

HYDRATED LIME IN PORTLAND CEMENT

specific gravity apparatus. The normal consistency of the neat paste was determined by means of a Vicat needle, similar to that in figure 2.

The accelerated test on the pats was made in a steam oven, about 5" x 30" x 15" in size, with shelves above the water line so that the pats were continually kept in a steam bath.

A temporary apparatus was erected to determine the density of the hydrated lime and the Portland cement. The "45 degree" method is shown in figure 3 and the "Sieve" method in figure 4.

The machine used for testing the briquettes was a 1000# Riehle shot machine similar to that shown in figure 5. The cubes were tested in a 10000# Olsen testing machine, shown in figure 6.

A - Details for Briquette
B - Details for Gang Mould

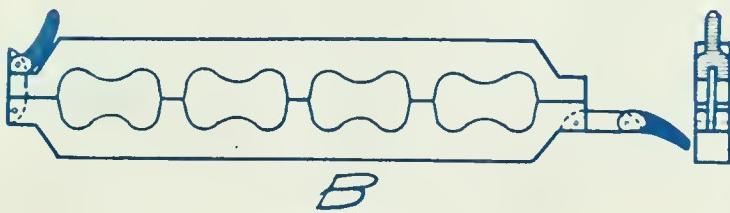
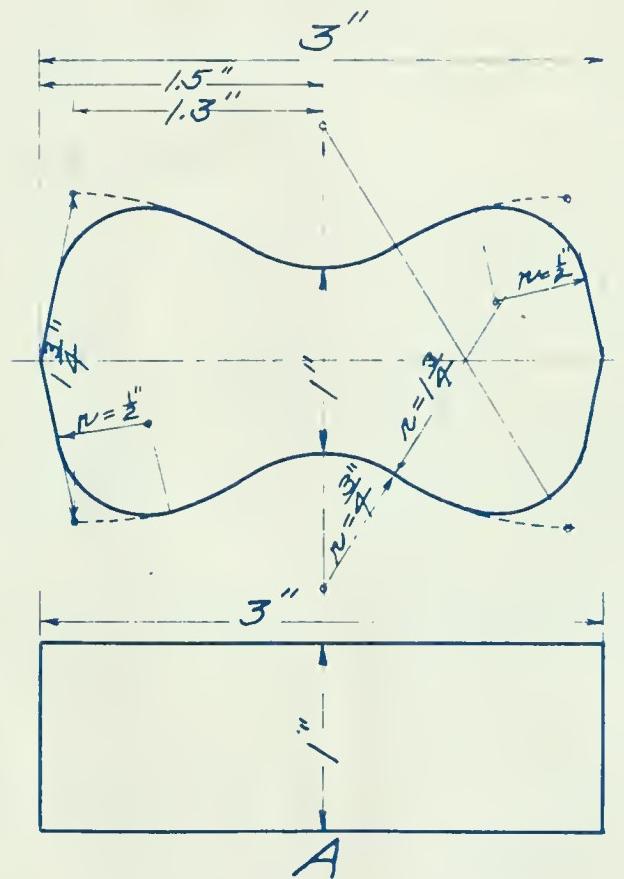


Figure 1.



Figure 2

"45°" METHOD

Determination of Density of Lime and Cement

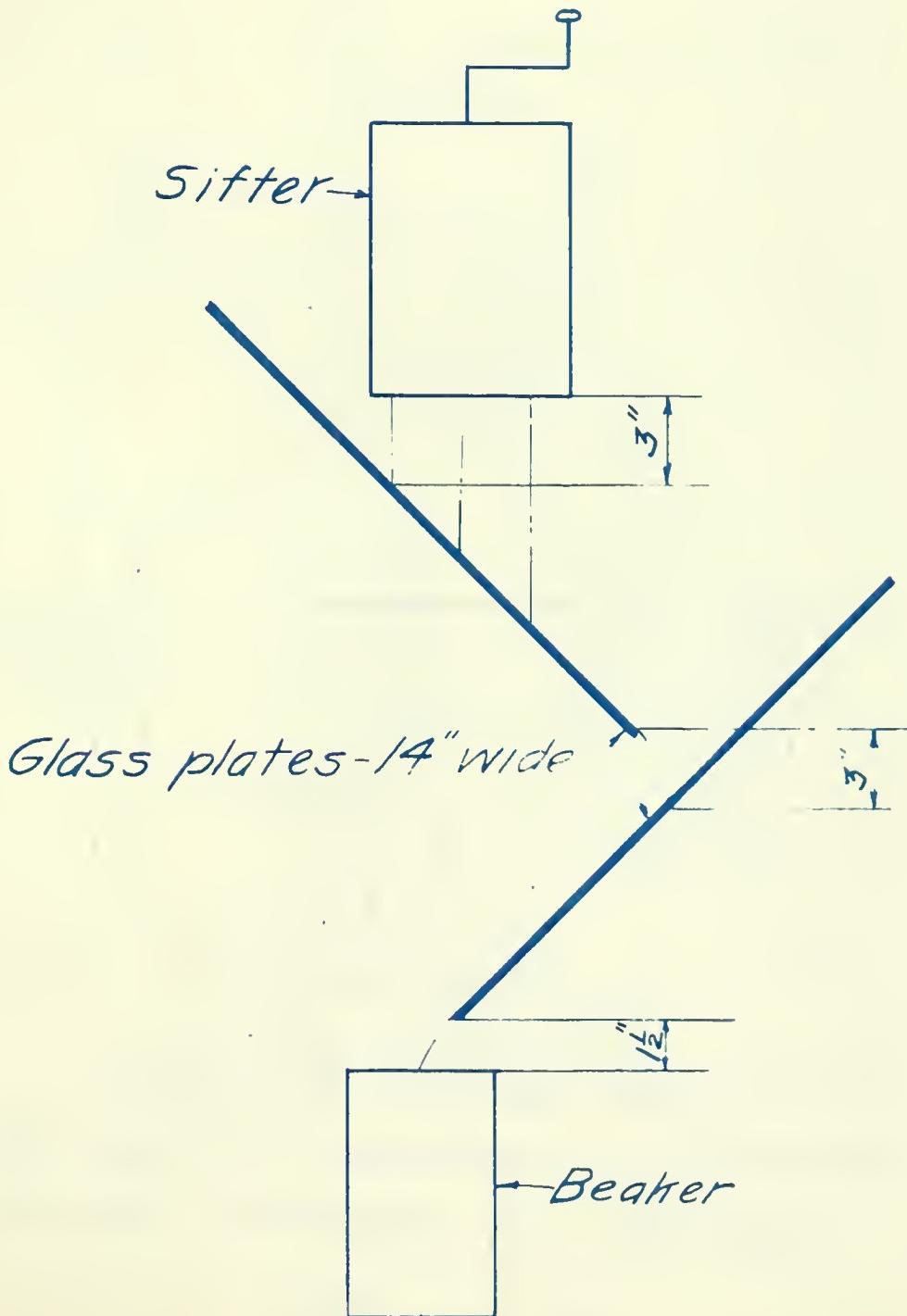
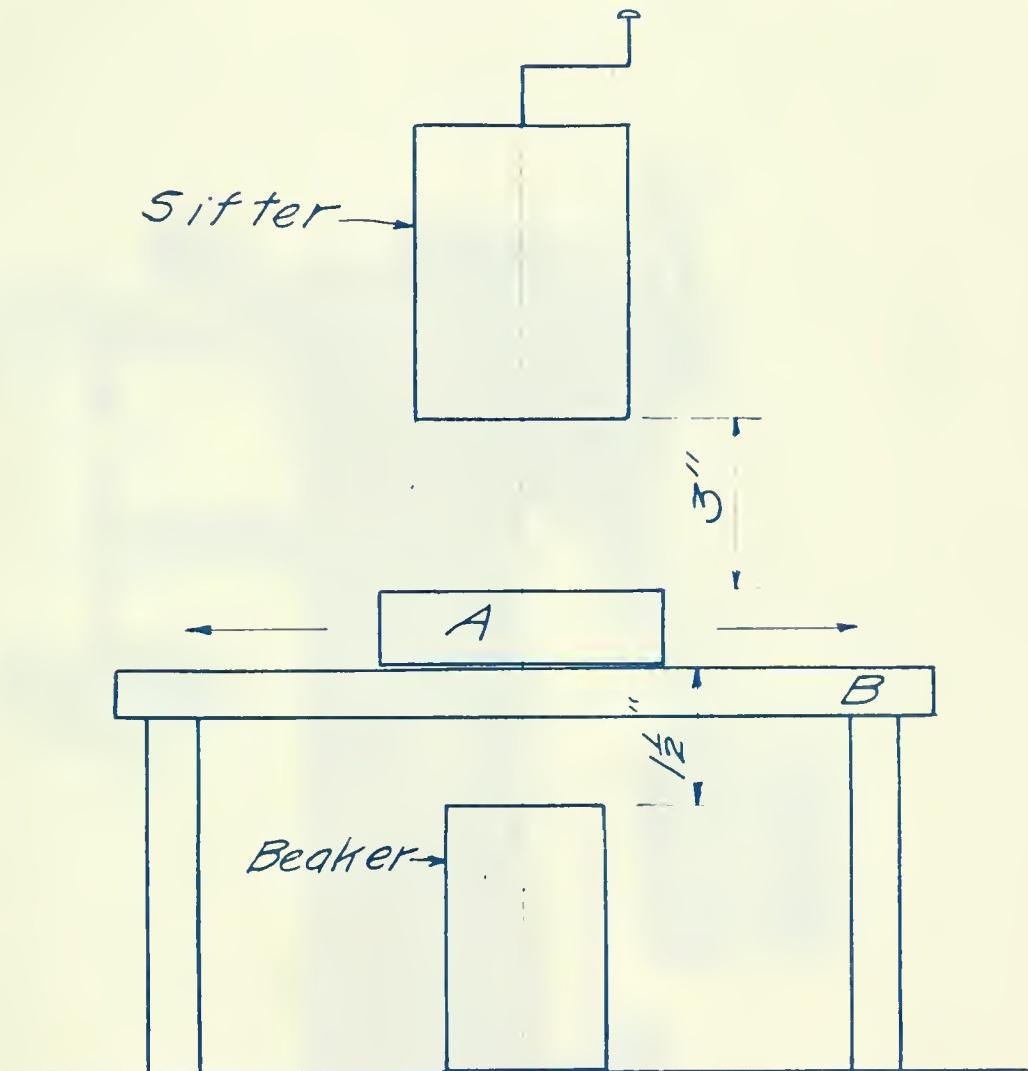


Figure 3

"SIEVE" METHOD

Determination of Density
of Lime and Cement



Sieve A moved horizontally on bars B allowing material to fall through to Beaker.

Figure 4

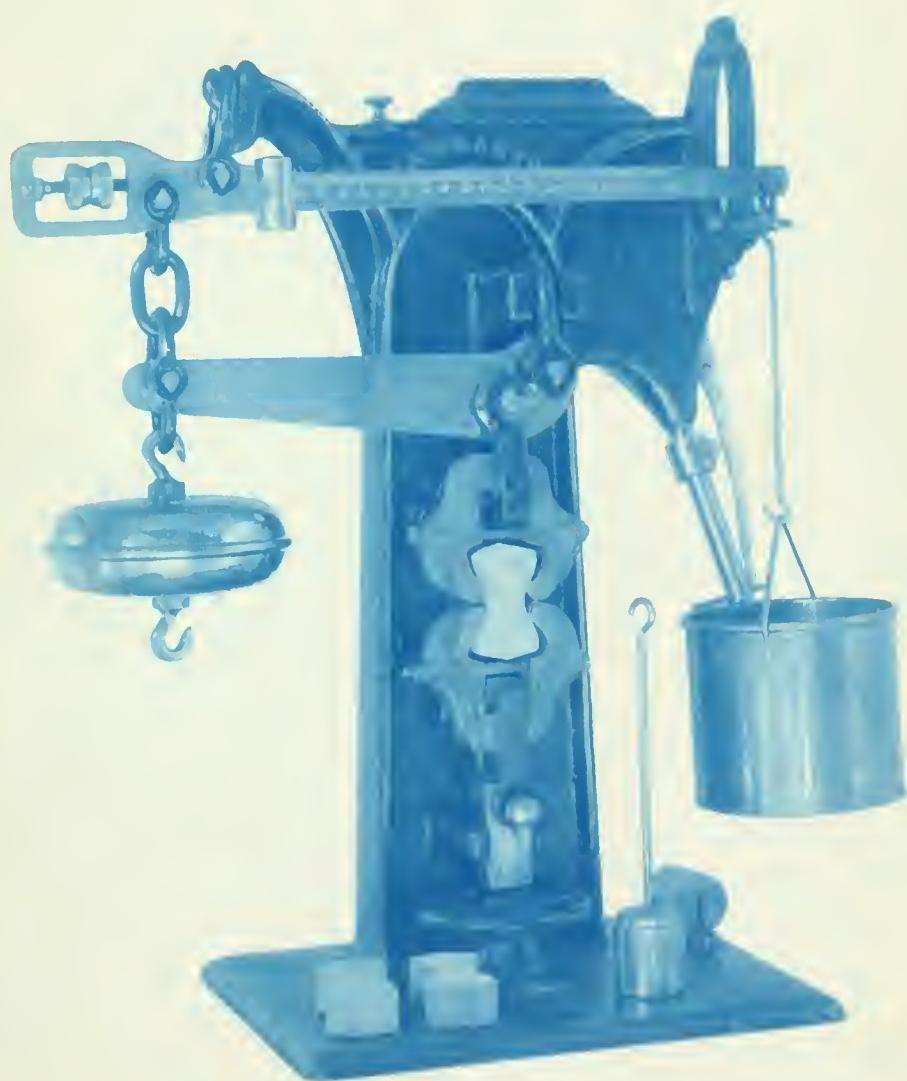


Figure 5

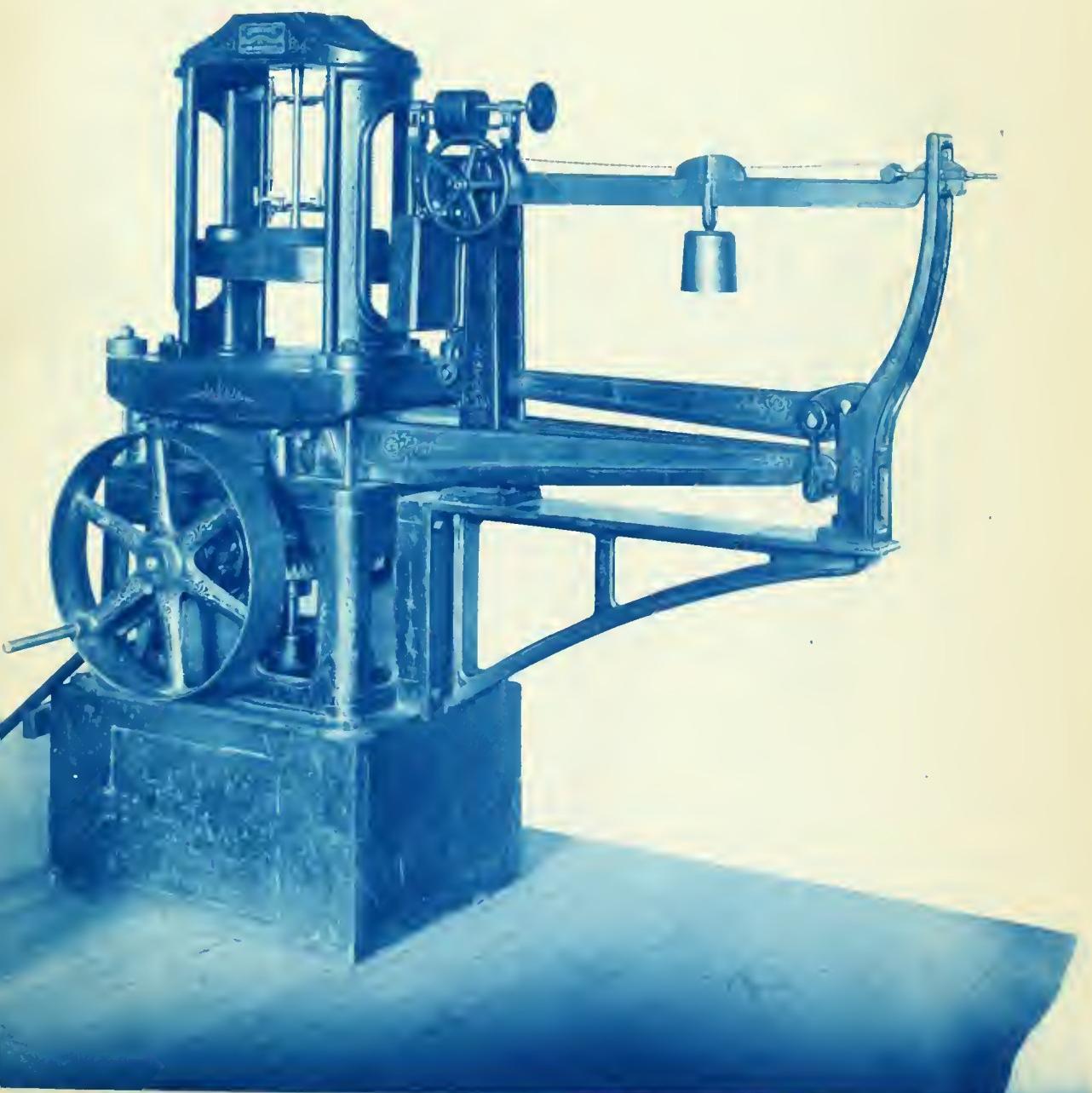


Figure 6

MATERIALS USED

The Portland cement used was from the Mitchell Mills of the Lehigh Portland Cement Company and had the following chemical composition:

Silica	- - - - -	21.50%
Oxide of Iron)	
)	- - - 8.84%
Alumina)	
Oxide of Lime	- - - -	62.09%
Oxide of Magnesia	- -	3.06%
Loss, SO ₃	- - - -	1.47%

The following figures relative to the Portland cement are the average results of two determinations.

Specific gravity - - - 3.10

Fineness -

4.1% retained on No. 100 sieve

18.2% retained on No. 200 sieve

Normal consistency - - - 24%

Time of initial set - 3 hrs. 15 min.

Time of final set - - 4 hrs. 15 min.

HYDRATED LIME IN PORTLAND CEMENT

The cement for these tests was taken direct from bin without being previously ignited.

The lime used was the Mitchell Lime Company's hydrate of the following chemical composition.

Calcium Oxide - - - 72.70%

Silica)
Iron and Alumina) 1.44%
)

Magnesium oxide - - 1.59%

Sulphuris - - - - .69%

Loss - - - - - 23.42%

The fineness of the lime as determined by two tests was as follows:

0.6% retained on the No. 100 sieve

0.95% retained on the No. 200 sieve

Note: The residue on the No. 100 sieve was discolored and was apparently largely foreign material.

The sand used was standard Ottawa sand, screened to pass a No. 20 sieve and be retained on a No. 30 sieve.

DESCRIPTION OF TESTS

Proportions

The tests were made on mortars of one part cement and lime to two parts sand, and one part cement and lime to three parts sand. A parallel set of tests was also made on neat cement test pieces. The addition of stone should cause no change in results if added in such proportions that the voids are properly filled.

The proportions used were taken according to weight measurement, the total of lime and cement being taken as one part of the mixture to a definite number of parts of sand. In the laboratory data given in Part 2, the lime is taken as a certain percentage of the cement. Should it be desired to convert the lime percentage into a percentage of the total lime and cement, the curve and table of Plate 1 may be used. The curves of Plates 6 to 17 inclusive give the strength in terms of the percent of the total lime and cement. The volume rela-

HYDRATED LIME IN PORTLAND CEMENT

tions are shown in the curves of Plates 18 to 23 inclusive.

On some jobs, volume measurements are used. In order that the results obtained might be given in terms of volume measurements, the density of the lime and cement was determined. While these densities may not be strictly correct, yet they are relatively correct, since the lime and cement determinations were made by the same methods and under the same conditions. An average of six determinations by two methods was taken as the correct density of the lime and cement. The data for the "sieve" method follows:

	Wt. of lime and beaker	Wt. of beaker	Wt. of Lime
1.	212.1	100.2	111.9
2.	211.6	100.2	111.4
3.	211.5	100.2	111.3
4.	210.5	100.2	110.3
5.	212.0	100.2	111.8
6.	212.7	100.2	112.5
	Average		<u>111.56</u>

the first time in the history of the world.

It is the first time in the history of the world.

It is the first time in the history of the world.

It is the first time in the history of the world.

It is the first time in the history of the world.

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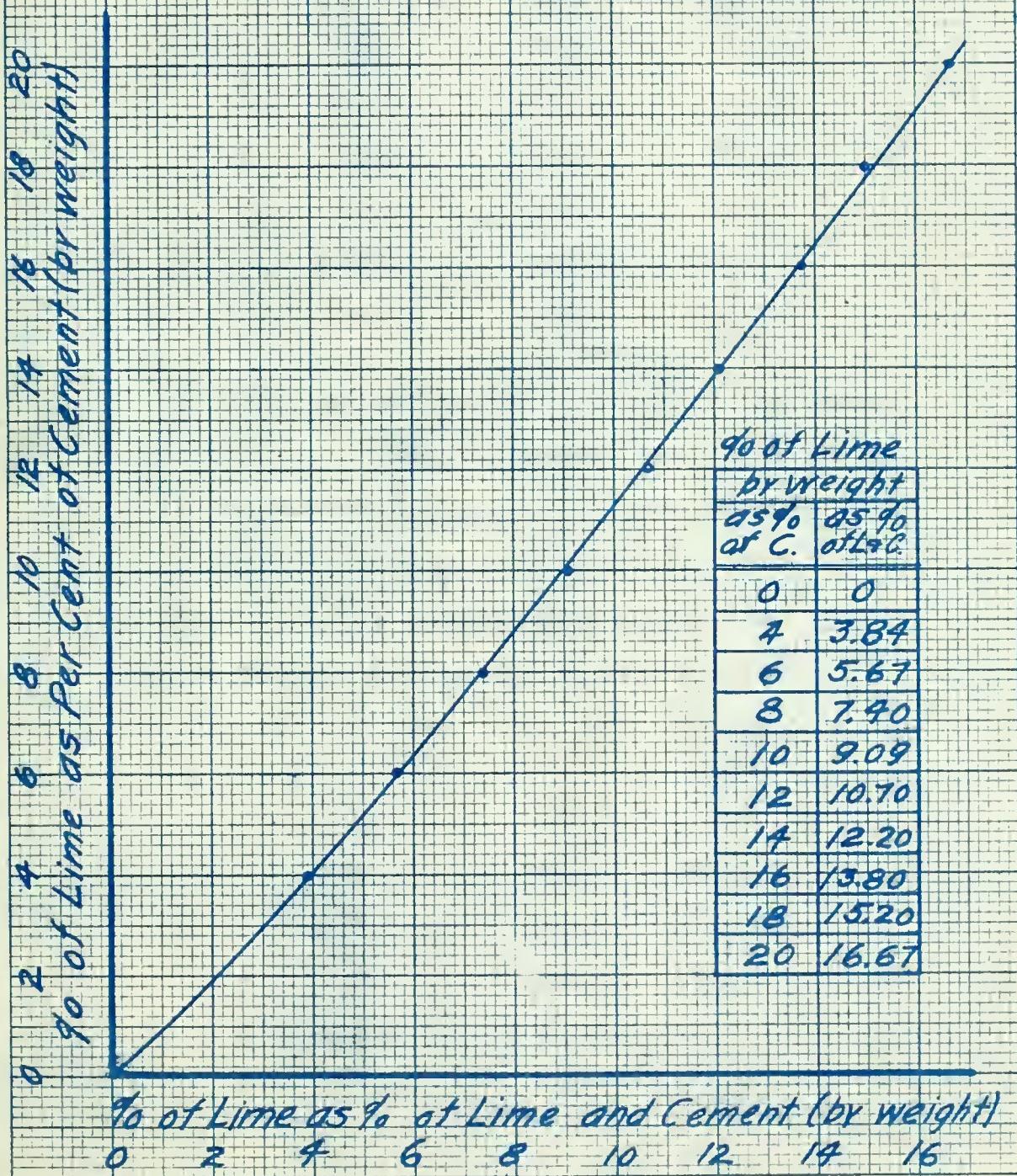
It is the first time in the history of the world.

It is the first time in the history of the world.

FREEMAN AND SNOW

PLATE I

Curve Showing Relation Between
 Percentage of Lime, as Percent of Cement
 (by weight) to Per Cent of Lime and
 Cement (by weight)





HYDRATED LIME IN PORTLAND CEMENT

	Wt. of Cement and beaker	Wt. of beaker	Wt. of Cement
1.	418.9	100.2	318.7
2.	420.6	100.2	320.4
3.	420.4	100.2	320.2
4.	422.6	100.2	322.4
5.	424.1	100.2	323.9
6.	435.0	100.2	329.8
		Average	<u>322.5</u>

The "sieve" method is shown in the sketch of figure 4. The "45 degree" method is shown in the sketch in figure 3. Note the height of fall is the same in both methods. This was done to insure a uniformity of results. The data for the "45 degree" method follows:

	Wt. of Lime and beaker	Wt. of beaker	Wt. of Lime
1.	211.3	100.2	111.1
2.	210.4	100.2	110.2
3.	211.85	100.2	111.65
4.	208.6	100.2	108.4
5.	209.3	100.2	109.1
6.	210.6	100.2	<u>110.4</u>
		Average	<u>108.47</u>

HYDRATED LIME IN PORTLAND CEMENT

Note: Weights are given in grams.

The weight of the beaker was taken as the average of three weighings.

The average value of the lime by the two methods was taken as 110.0 grams.

The volume of the beaker was taken as 275 cc., the average of two determinations.

From the above data, the density of the lime and cement was determined as follows:

$$\text{Wt. of cement} \quad \frac{322.5}{275} = 1.17 \text{ gms/cc.}$$

$$\text{Wt. of lime} \quad \frac{110.0}{275} = 0.4 \text{ gms/cc.}$$

$$\frac{0.4}{1.17} \times 100 = 34.15\%$$

Density of lime is 0.3415 as compared with cement.

The curve and table of Plate 2, shows the relation between the percent of lime (by weight) of the total lime and cement. The curves in figures to inclusive give the strength results in terms of the percentage of lime by

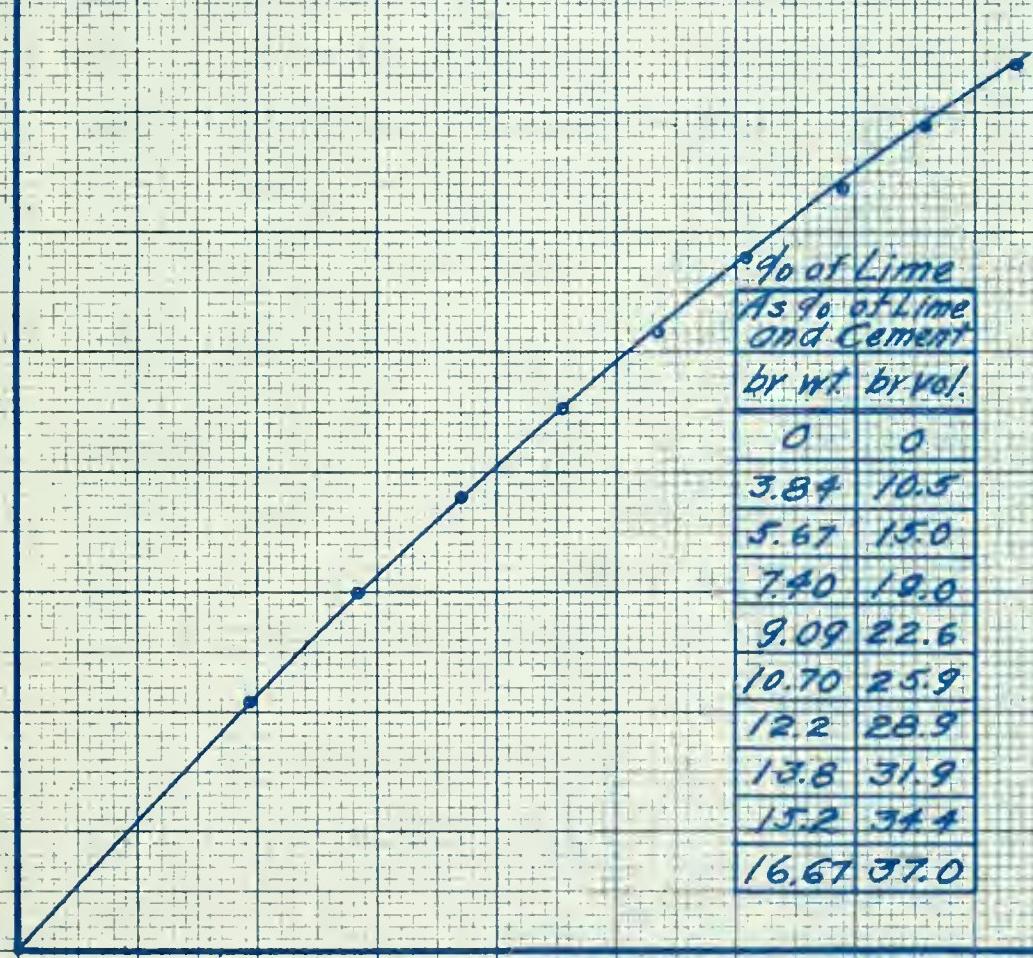
FREEMAN AND SNOOK

PLATE 2

Curve Showing Relation Between
 Percentage of Lime, as % of Lime and
 Cement (by Volume) to % of Lime
 and Cement (by Weight)

% of Lime as % of Lime and Cement (by Volume)

% of Lime as % of Lime and Cement (by weight)



% of Lime
 As % of Lime
 and Cement
 by wt. by vol.

0	0
3.84	10.5
5.67	15.0
7.40	19.0
9.09	22.6
10.70	25.9
12.2	28.9
13.8	31.9
15.2	34.4
16.67	37.0

HYDRATED LIME IN PORTLAND CEMENT

volume.

The formula used for converting the weight measurements was derived as follows:

Let m = reciprocal of density of cement

Let km = reciprocal of density of lime

$$mx \% \text{ of cement (by wt.)} = \text{vol. of cement} = X$$

$$kmx \% \text{ of lime (by wt.)} = \text{vol. of lime} = Y$$

$$\text{Total vol. of lime and cement} = X + Y$$

$$\text{Proportion (by vol.) of lime} = \frac{Y}{X + Y}$$

$$\frac{1}{m} = 1.17 \quad m = 0.855$$

$$\frac{1}{km} = 0.4 \quad km = 2.5$$

Example:

$$\begin{aligned} \% \text{ of cement (by wt.) of total lime and} \\ \text{cement} &= 96.16 \end{aligned}$$

$$\begin{aligned} \% \text{ of lime (by wt.) of the total lime and} \\ \text{cement} &= 3.84 \end{aligned}$$

$$.855 \times 96.16 = 82.216 = X$$

$$2.5 \times 3.84 = 9.6 = Y$$

$$\frac{9.6}{82.216 + 9.6} \times 100 = 10.5\% \text{ or percentage of lime (by vol.) of the total lime and cement.}$$

HYDRATED LIME IN PORTLAND CEMENT

Time of Set

The addition of lime to the neat paste increased the time of initial and final set as shown in the curves of Plate 3.

Consistency

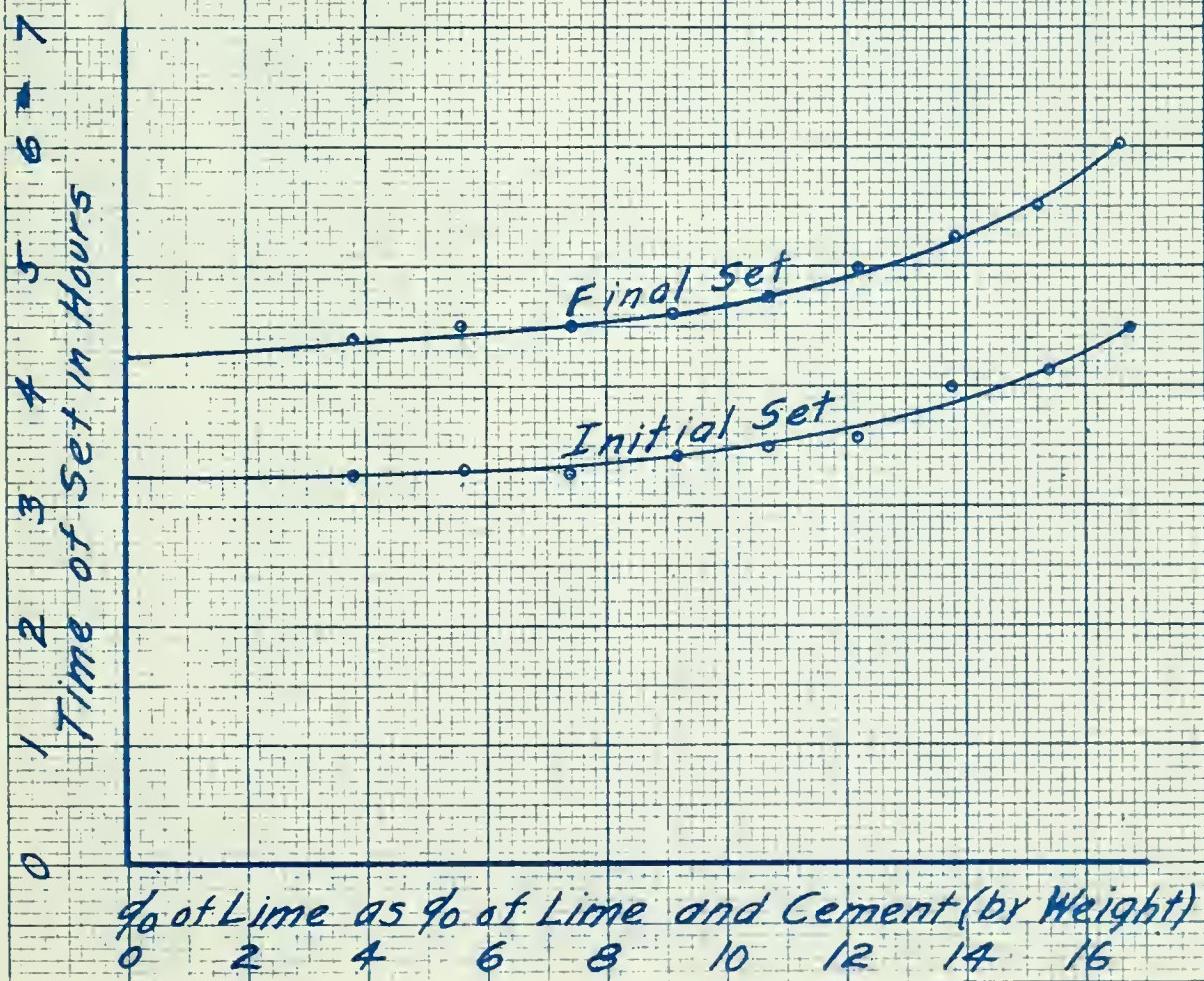
The normal consistency of all neat pastes was determined by means of the Vicat apparatus, shown in figure 2. The effect upon the normal consistency of the cement produced by the addition of lime is clearly shown in the data. The gradual increase is shown at a glance by referring to the curve of Plate 4.

Feret's percentage of water for Portland cement mortar of standard consistency, tabulated in Plate 5, was used in determining the consistency of mortars. These figures agree very closely with the results of formulas commonly used to obtain this result. The mortars were in all cases of a quaking consistency; water could easily be brought to the surface under the pressure of the trowel.

FREEMAN AND SNOOK

PLATE 3

Curves Showing Relation Between
 Initial and Final Sets of Neat Cement
 Paste and % of Lime, as % of
 Lime and Cement (by weight)



FREEMAN AND SNOW

PLATE 4

Curve Showing Relation Between
Normal Consistency of Neat Paste
and Percentage of Lime,
as % of Lime and Cement (by weight)

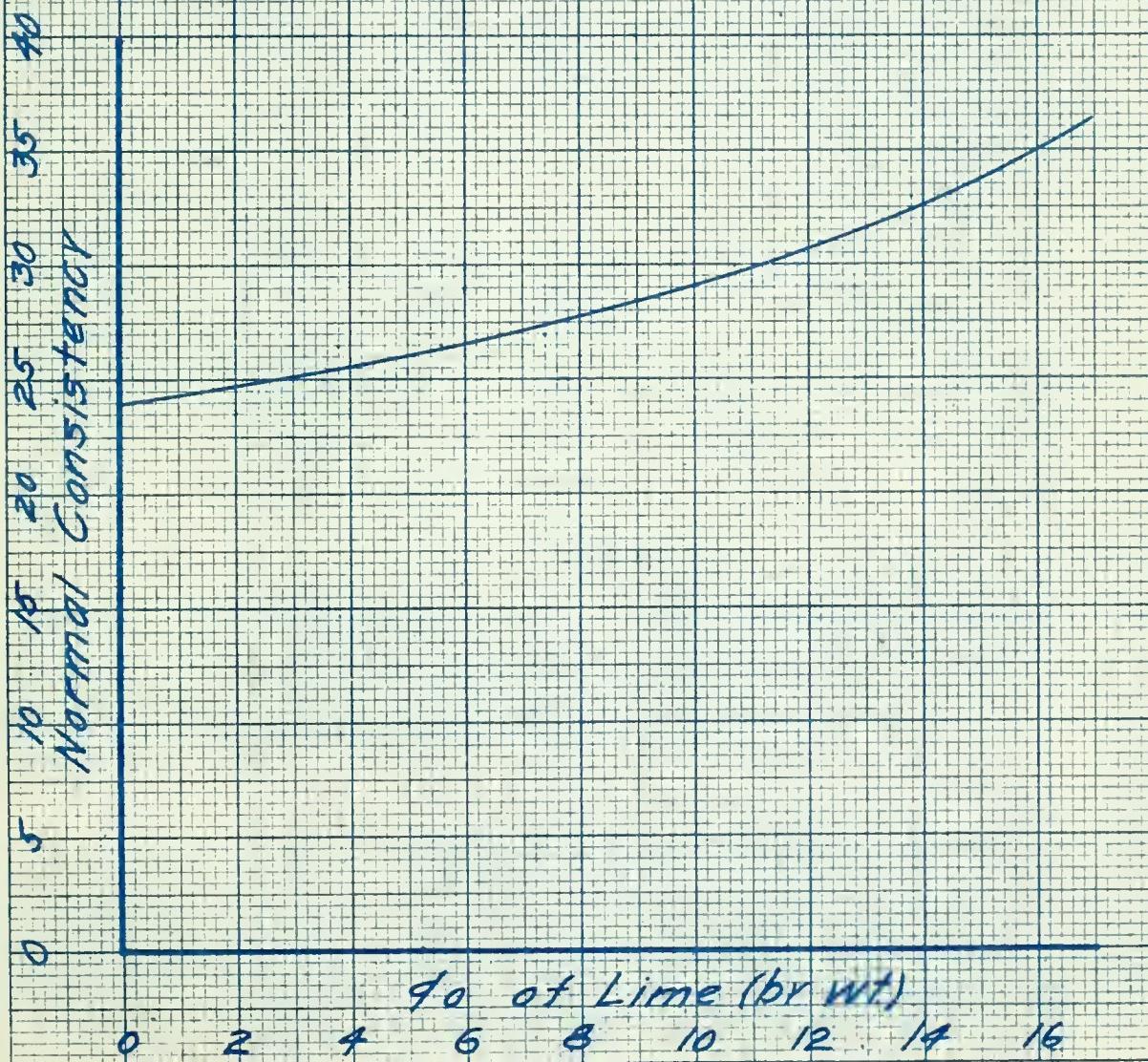




PLATE 5

Feret's Percentages of
Water for Portland Cement Mortar
of Standard Consistency

% of Neat Cement Mortar	Per Cent of Water in Terms of Cement and Sand				
	1:1	1:2	1:3	1:4	1:5
18	12.0	10.0	9.0	8.4	8.0
19	12.3	10.2	9.2	8.5	8.1
20	12.7	10.4	9.3	8.7	8.2
21	13.0	10.7	9.5	8.8	8.3
22	13.3	10.9	9.7	8.9	8.4
23	13.7	11.1	9.8	9.1	8.5
24	14.0	11.3	10.0	9.2	8.6
25	14.3	11.6	10.2	9.5	8.8
26	14.7	11.8	10.3	9.5	8.9
27	15.0	12.0	10.5	9.6	9.0
28	15.3	12.2	10.7	9.7	9.1
29	15.7	12.5	10.8	9.9	9.2
30	16.0	12.7	11.0	10.0	9.3
31	16.3	12.9	11.2	10.1	9.4
32	16.7	13.1	11.3	10.3	9.5
33	17.0	13.3	11.5	10.4	9.6
34	17.3	13.6	11.7	10.5	9.7
35	17.7	13.8	11.8	10.7	9.9
36	18.0	14.0	12.0	10.8	10.0
37	18.3	14.2	12.2	10.9	10.1
38	18.7	14.4	12.3	11.1	10.2
39	19.0	14.7	12.5	11.2	10.3
40	19.3	14.9	12.7	11.3	10.4
41	19.7	15.1	12.8	11.5	10.5
42	20.0	15.3	13.0	11.6	10.6
43	20.3	15.6	13.2	11.7	10.7
44	20.7	15.8	13.3	11.9	10.8
45	21.0	16.0	13.5	12.0	11.0
46	21.3	16.1	13.7	12.1	11.1

HYDRATED LIME IN PORTLAND CEMENT

Mixing

All materials were weighed. The cement and lime were spread evenly on the glass plate and mixed dry before adding the sand. The aggregate was again mixed dry after the sand was added. A crater was then made in the center and the proper percentage of water added. The materials were turned from the outer edge into the crater with the aid of the trowels, until all the water was absorbed. The mass was then kneaded for about two minutes when it appeared to be perfectly mixed. A single batch, of approximately 3000 grams, was mixed to make fifteen briquettes, fifteen cubes and from three to five pats.

All batches were mixed by the same man who attempted a uniformity of procedure.

Moulding

The moulds, with inner surfaces oiled, were placed on glass plates. The paste or mortar was pressed into the moulds, care being taken

HYDRATED LIME IN PORTLAND CEMENT

to put the same pressure on each test piece, and the surface struck off and smoothed with a trowel.

Storage

All test pieces were kept in the moist cabinet for approximately twenty-four hours, the exact number of hours being noted on the data sheets. The moulds were then removed and the one-day test made. The remaining test pieces were kept immersed in water in the storage pans until tested. One pat was kept immersed in water and one exposed to the air, and observed at intervals for any track of cracking, distortion, checking or disintegrating.

Testing

The one-day test was made as soon as the moulds were removed. The other tests were made as soon as the test pieces were taken from the pans, on the proper day. Three test pieces of each batch were tested, one day, seven days, and twenty-eight days after date of mixing, an average of three being taken as the correct value.

HYDRATED LIME IN PORTLAND CEMENT

The test picces were tested in the machines previously noted. The cubes were placed on a ball and socket block and between two blotters so that the pressure would be more evenly distributed.

Besides the pats previously mentioned, after being in the moist cabinet for twenty-four hours, a third pat was placed in a steam bath for five hours and observed for the same defects as were noted in the others.

RESULTS OF TESTS

As previously mentioned, all the data has been plotted in the form of curves. It is not claimed that these curves are perfectly accurate, i.e., drawn thru the exact points. Under the assumption that the results would be more or less uniform, the curves were drawn to represent a fair average of the points plotted. Only after careful investigation were they drawn.

Although there were several departures from expected results, yet it may be said that they were, in general, uniform.

The form and evenness of texture of the briquette were highly satisfactory, being exceedingly uniform.

Owing to shrinkage, (especially in the pieces containing the higher percentages of lime) and the small size of the cubes, it was noticed that some of the pieces were not true cubes.

Lack of uniformity, in the tests of the cubes (though not seriously so) may be partly

HYDRATED LIME IN PORTLAND CEMENT

attributed to this.

As could be deduced from the above, it was noticed that the amount of shrinkage in setting increased with the percentage of lime added. With the exception of the two highest percentages of lime in the neat cement, however, the pats showed no signs of cracking or disintegrating in either the water, air or accelerated tests.

The one-day tests were not as satisfactory as the other tests, though they were up to standard.

The Standard Specifications for Portland Cement adopted by the American Society for Testing Materials and other engineering societies, contains the following paragraph on

TENSILE STRENGTH

"The minimum requirements for tensile strength of briquettes, one square inch in cross section, shall be as follows, and the cement shall show no retrogression in strength within the periods specified:

Some interesting observations

On the subject of

the 11th century and the 12th century church at
Wimborne Minster. The former was built mostly
about 1100, the latter about 1150.

The first had a single tower and a single
chancel, while the second had mostly
single bays and single aisles, and the choir
had three bays and three aisles. The main
aisle had three bays and three aisles.

Thus

the first was built in 1100, and the second in 1150.
The former had a single tower and a single chancel,
while the latter had three bays and three aisles, and
the choir had three bays and three aisles.

Conclusion

Thus the two churches are very similar, both
in their exterior and interior. The former
had a single tower and a single chancel,
while the latter had three bays and three aisles, and
the choir had three bays and three aisles.

Thus the two churches are very similar,

HYDRATED LIME IN PORTLAND CEMENT

Age	Neat Cement	Strength
24 hours (in moist air)		175#
7 days (one day in moist air, 6 in water)	500#	
28 days (one day in moist air, 27 in water)	600#	

One Part Cement, Three Parts Standard
Ottowa Sand

7 days (one day in moist air, 6 in water)	200#
28 days (one day in moist air, 27 in water)	275#

By referring to the curves of Plates 6, 7 and 8, it will be seen that the addition of 12% (by weight) hydrated lime, does not weaken the neat paste enough to bring the tensile strength below the minimum allowed value. It is also shown that the addition of 8% hydrated lime to the 1:3 mortar gives strength results above the standard requirements.

No increase in tensile strength which some investigators say should result, was noted when small percentages of hydrated lime were added to the cement mortar.

It may be taken as a general rule, that the

HYDRATED LIME IN PORTLAND CEMENT

compressive strength of a material increases with the tensile strength. Merriman gives the compressive strength of one month old neat Portland cement paste as 3000 pounds per square inch. By referring to the curves of Plate 10, it will be seen that with the addition of 16-2/3% (by weight) of hydrated lime, the value of neat cement is 3000 pounds per square inch. Merriman gives the strength of hydraulic mortars as 6 to 10 times the tensile strength. The standard German specifications require the compressive strength of concretes and mortars to be at least ten times their tensile strength. In the compression curves, it will be seen that the compressive strength exceeds in the majority of cases the tensile strength in the proportion of more than 10 to 1. This agrees very favorably with the above three statements.

It was found in both the neat paste and cement mortar tests, that the compressive strength increased with a small addition (4 or

HYDRATED LIME IN PORTLAND CEMENT

5%) of hydrated lime.

Enough test pieces were made to complete the three months and one year test (previously mentioned) but only enough time has elapsed to allow of a few three months tests. It is possible that some interesting results showing a fair increase in strength after the three months period, will be developed. This would, though, be more apt to occur, were the pieces allowed to set in the air since it is a known fact that the final set of lime occurs a long time after being placed, and only in air.

and the world without constraint.

and I had about 1/2

minutes to do what I wanted to do
I just did it. I was very nervous about
what would happen after I got home.
I was afraid that my parents would
be angry at me and that they would
not let me go to school again. But I was
able to calm myself down and I was able
to talk to my parents and explain what
had happened and why I had done it. They
were very understanding and supportive.
They told me that I made a mistake but
they also told me that I was a good person
and that they were proud of me. I am still
worried about what will happen if I get
caught but I know that I did the right thing
and that I will be okay.

CONCLUSION

We have seen that by the addition of hydrated lime to Portland cement, the following benefits resulted:

1. Increased plasticity, which
 - a) destroys the excess friction caused by the angular sand and stone particles, hence it becomes a lubricant.
 - b) makes mixing easier, hence cheaper labor expense and a better mix.
 - c) allows an easier flow, hence better for chute work, etc.
 - d) causes concrete to automatically fall into place, hence eliminating "stone pockets" and making certain of a complete covering of steel reinforcing.
2. Increased density, which
 - a) makes the concrete more water-proof, hence, the alternate wetting and drying, so detrimental to all concrete work, is largely eliminated. (Note: The Bureau of

ANSWER

The author's answer is as follows:

It is well known that the best way to
analyze any problem is to first understand
the problem well enough
to find a way to solve it.
This can be done by
writing down the problem and
then trying to solve it.
The author has been asked to
solve the following problem:
A man walks with
a child across a stream. He
cannot walk across the stream alone, and
he cannot leave his child
alone in the stream. How
can he get across the stream
with his child?

HYDRATED LIME IN PORTLAND CEMENT

Standards found hydrated lime to be the best adulterant, as concerns the impermeability of the cement, on the two weeks tests.

b) Increases the hardness or toughness, hence of particular value in road construction.

c) Eliminated white efflorescence of salts.

d) Gives whiter and more uniform color, (Haff).

3. Keeps an excess of moisture in concrete, thus

a) Holding enough moisture to allow a complete set of the comparatively slow acting cement combination.

b) Helping to prevent hair cracks on surface, due to lack of moisture.

In adding lime, we are adding a material which is in itself "mildly cementitious", and which (since both Portland cement and hydrated lime are neutral) causes no unknown or uncertain

4

• 17 •

HYDRATED LIME IN PORTLAND CEMENT

chemical actions to be set up, (Warner). Thus there need be no fear that some new action will take place.

The results of these tests show a gradual decrease in the tensile strength of Portland cement mortars, by increasing the proportion of hydrated lime. This decrease is not, however, of sufficient amount to condemn the use of hydrated lime in Portland cement. The advantages gained by its use are so numerous and of such great value, that they more than counterbalance the slight decrease in strength, (i.e. when the hydrated lime is used in the proper proportions).

It should be remembered that the kind of lime and cement used will materially affect the results. By referring to the chemical analysis of the lime and cement used, (see "Materials Used"), it will be seen that when we added the hydrated lime to the Portland cement, we added a lime high in calcium oxide to a cement already high in calcium oxide. Different results would

• 2 • 4 8 2 8

HYDRATED LIME IN PORTLAND CEMENT

most likely be obtained if a low calcium lime or cement, or a high dolomitic lime was used.

The fact that both the lime and cement were high in CaO, may account for the lack of increased tensile strength, which some investigators say should result from the addition of small percentages of hydrated lime to Portland cement.

Some investigators claim an increased, others a decreased strength of mortars containing hydrated lime, when the mortar is allowed to set under water. This varies with the percentage of lime. A mortar with a high percentage of lime will not set at all under water. In foundation work, it is then not desirable to have too much lime present, even though the strength required is not high.

In conclusion, the writers' wish is to strongly recommend the use of hydrated lime in Portland cement mortars and concrete, when used in the proper proportion. It is not advisable to use a leaner mix and add hydrated lime to

HYDRATED LIME IN PORTLAND CEMENT

keep the impermeability or other properties of the cement the same as those of a richer mix without the addition of the lime, but, with the same richness or mix, the adding of lime is highly desirable.

On unimportant work, a fairly high percentage of lime may be used. In the more important engineering jobs, where the strength is an important factor, the use of 12% (by weight), equivalent to about a 14% replacement of cement, of hydrated lime, will not lower the tensile strength below the minimum requirements.

Higher percentages may be used, depending on the character of the work.

Where it is desired to limit the use of hydrated lime within the requirements of the specifications on a job, the conditions under which the concrete is to be used, the kind of lime and cement used, and the strength required must be thoroughly investigated. When this is done, complete satisfaction will result.

HYDRATED LIME IN PORTLAND CEMENT

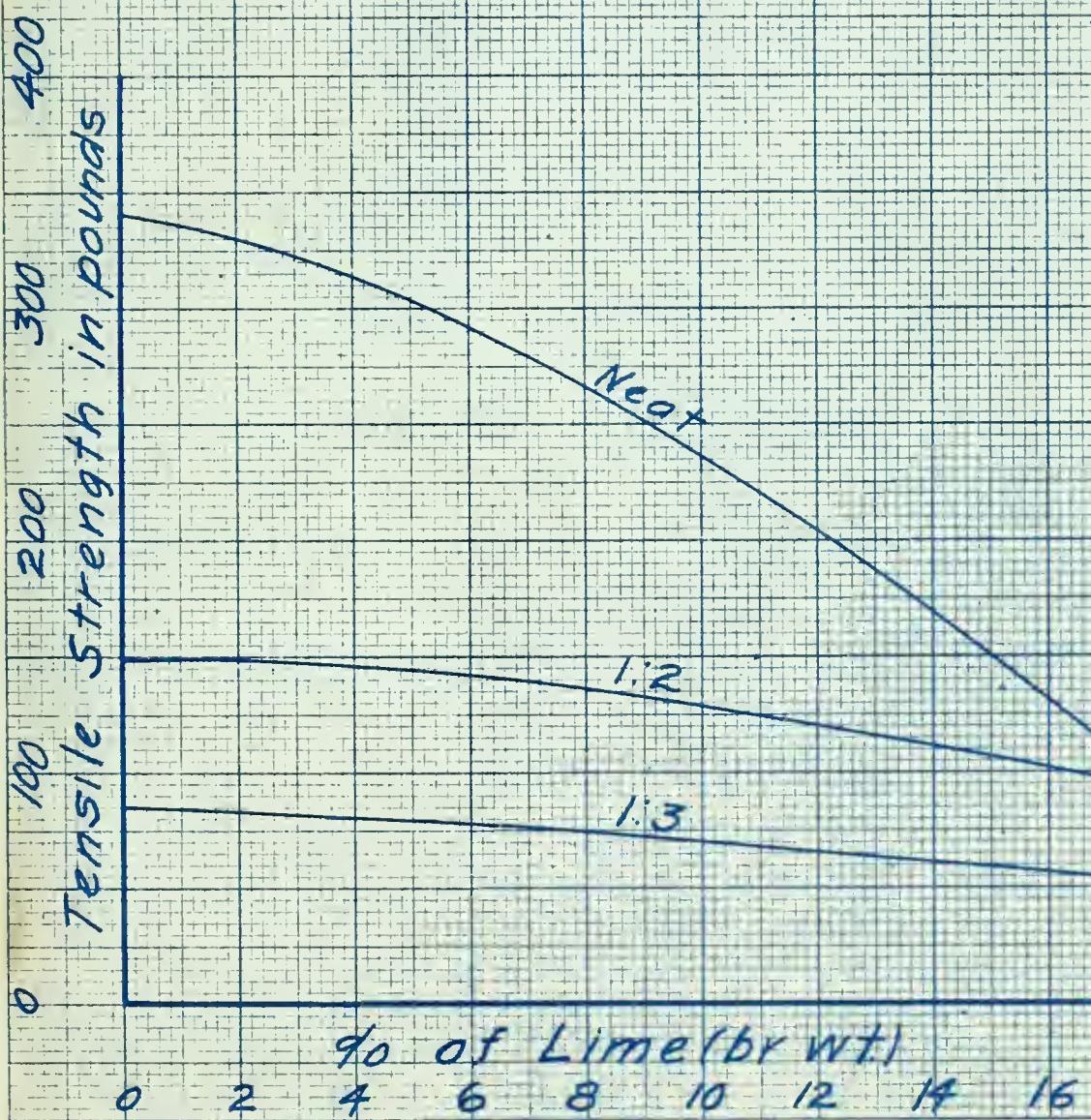
The writers hope that these experiments will be continued, taking among other things, the following into consideration:

1. Effect on the strength when the test pieces are allowed to set in air.
2. Effect on the strength by the addition of various percentages of dolomitic hydrated lime when the test pieces are allowed to set in water and in air.

STRENGTH CURVES

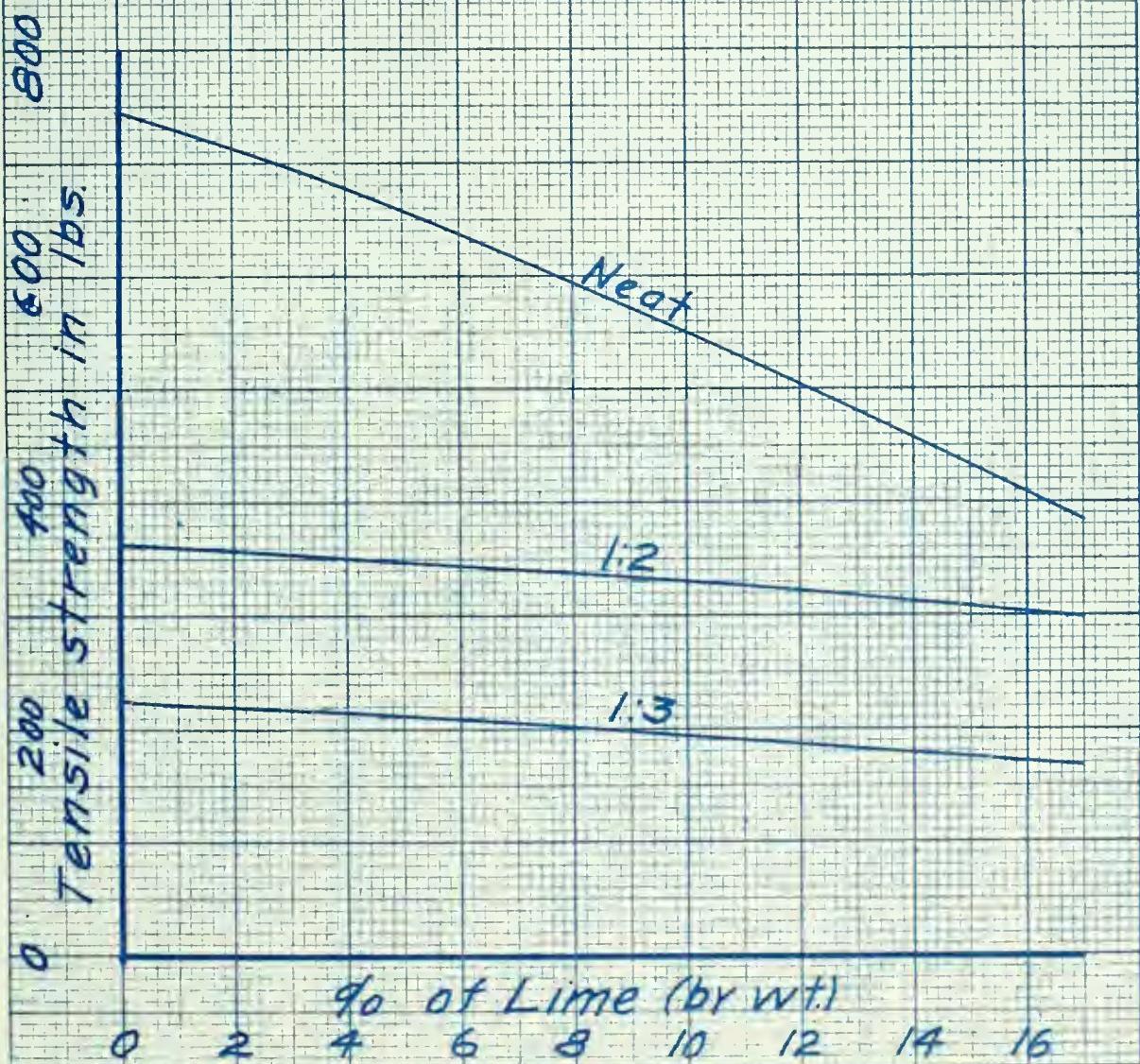
FREEMAN AND SNOW

PLATE 6
One day tests.



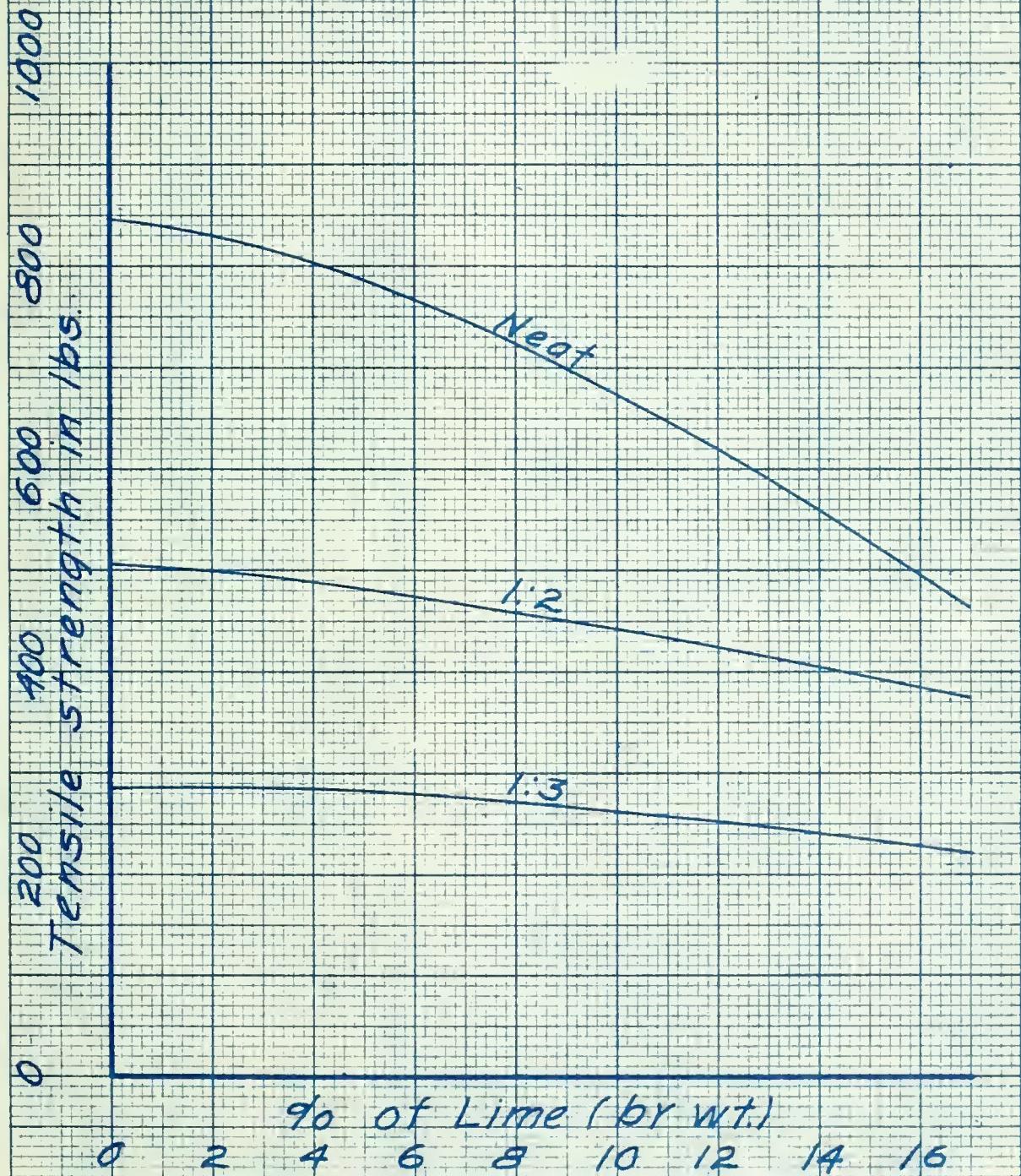
FREEMAN AND SNOW

PLATE 7
7 day tests



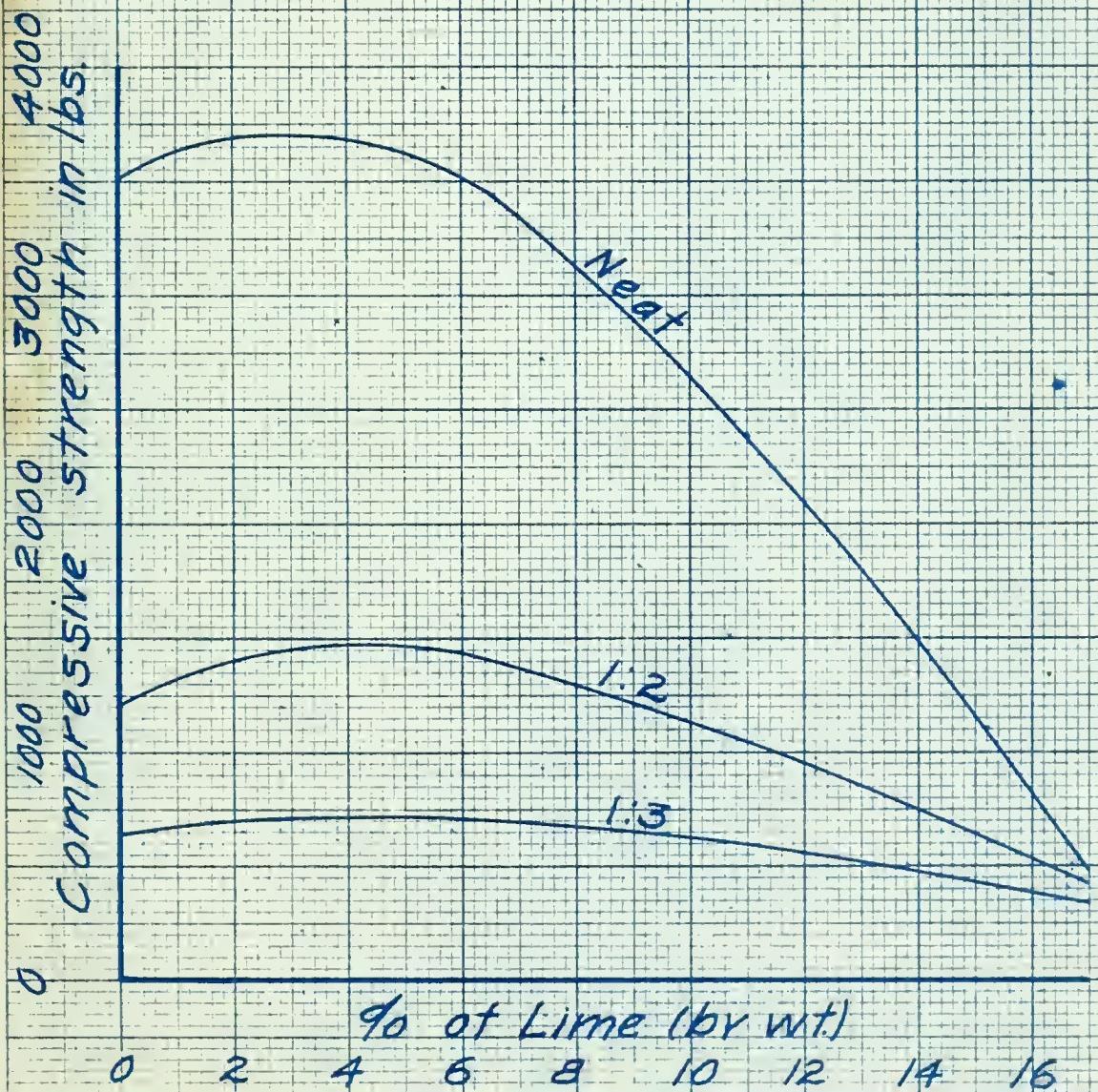
FREEMAN AND SNOW

PLATE 8
28 day tests



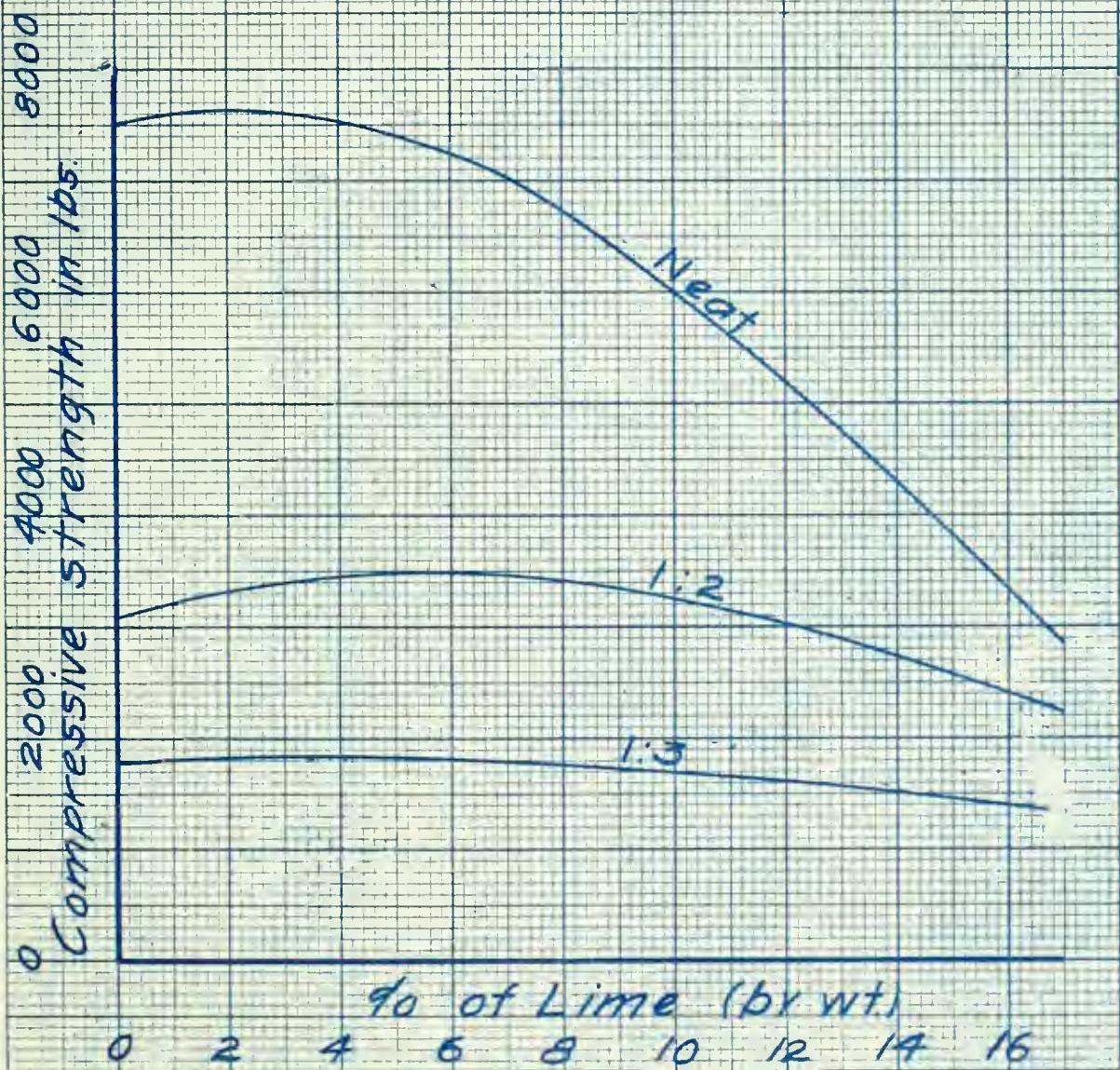
FREEMAN AND SNOW

PLATE 9
One day tests





FREEMAN AND SNOOK

PLATE 10
7 day tests

FREEMAN AND SNOW

PLATE II
28 dar tests

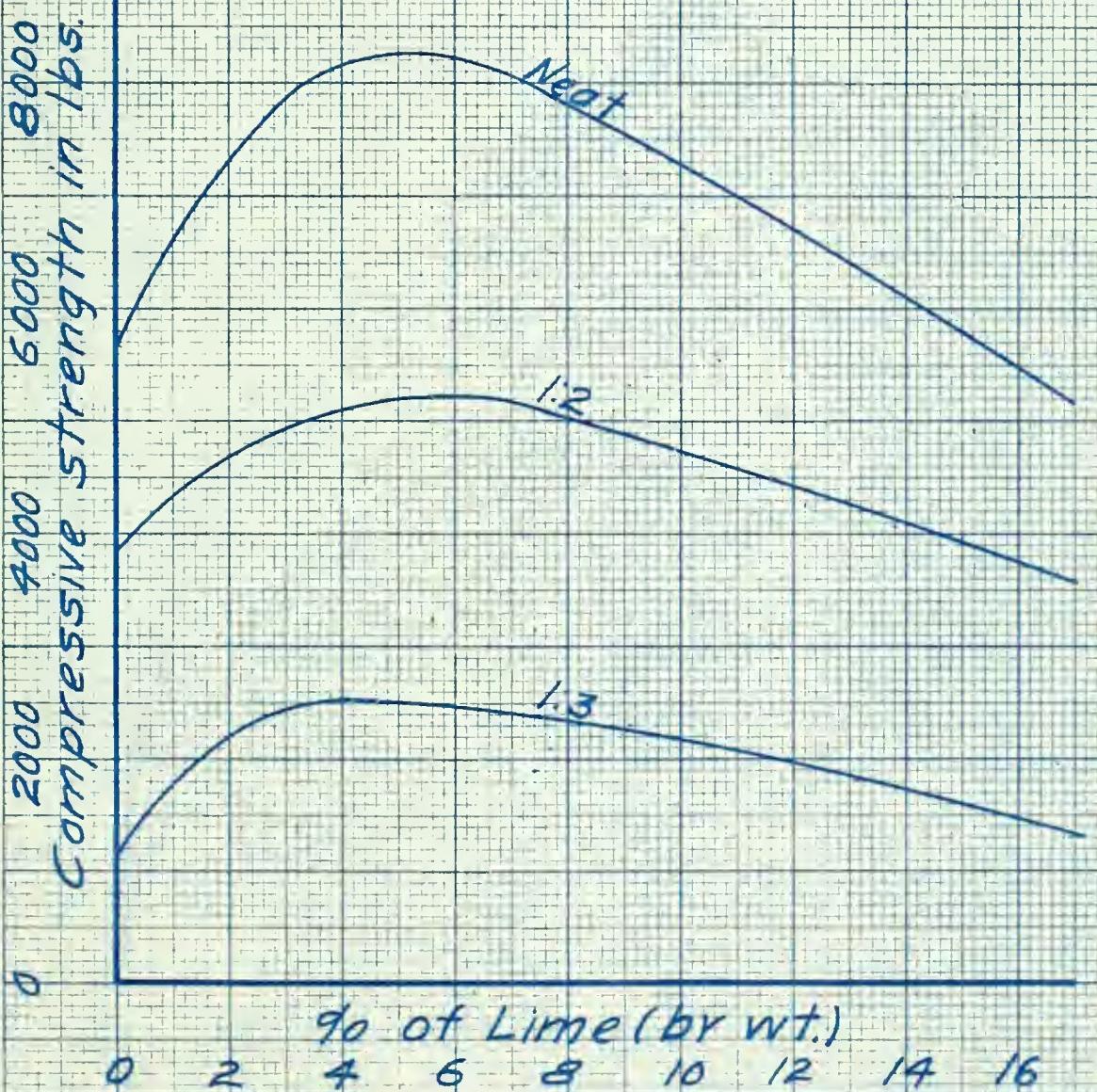
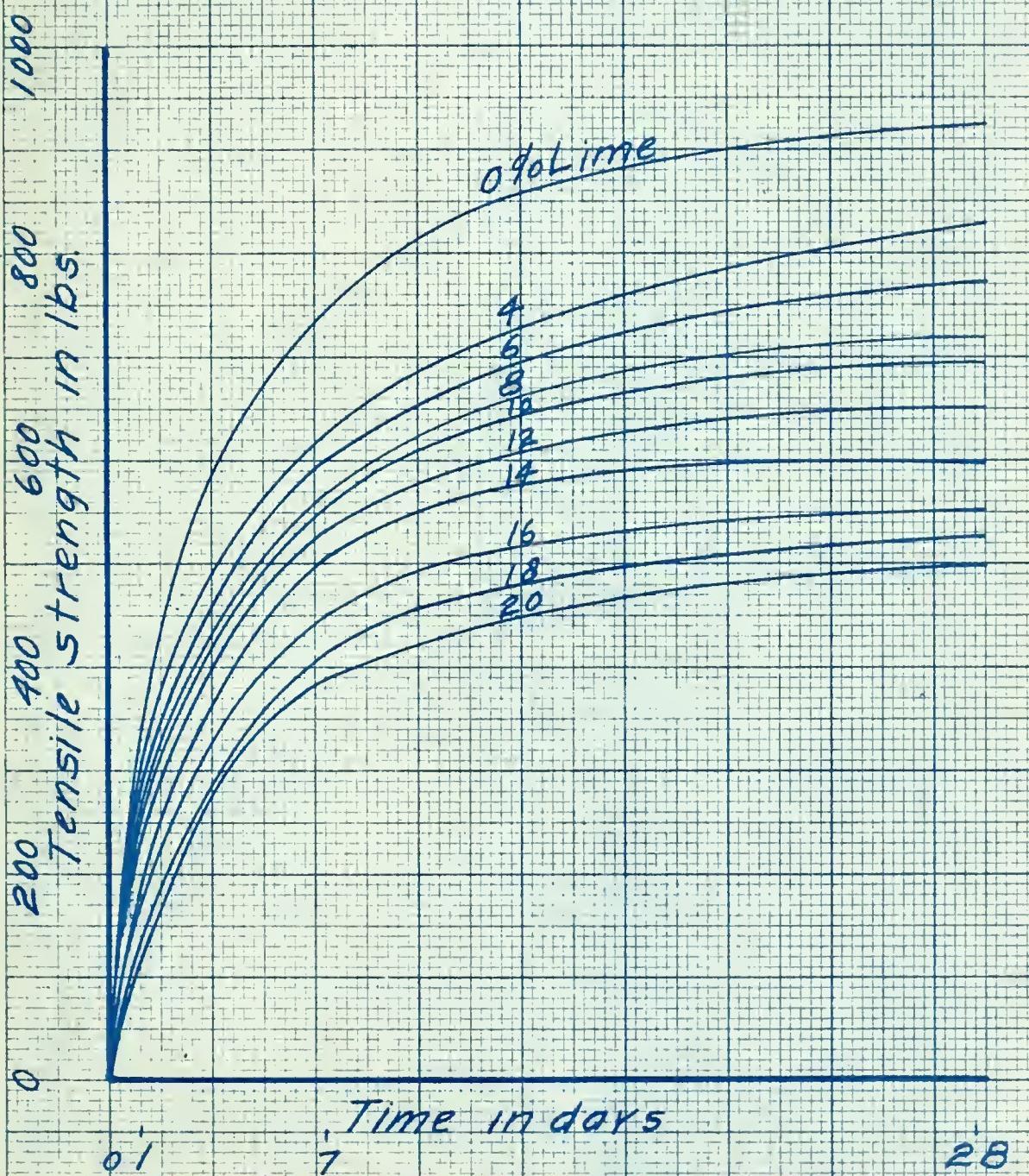
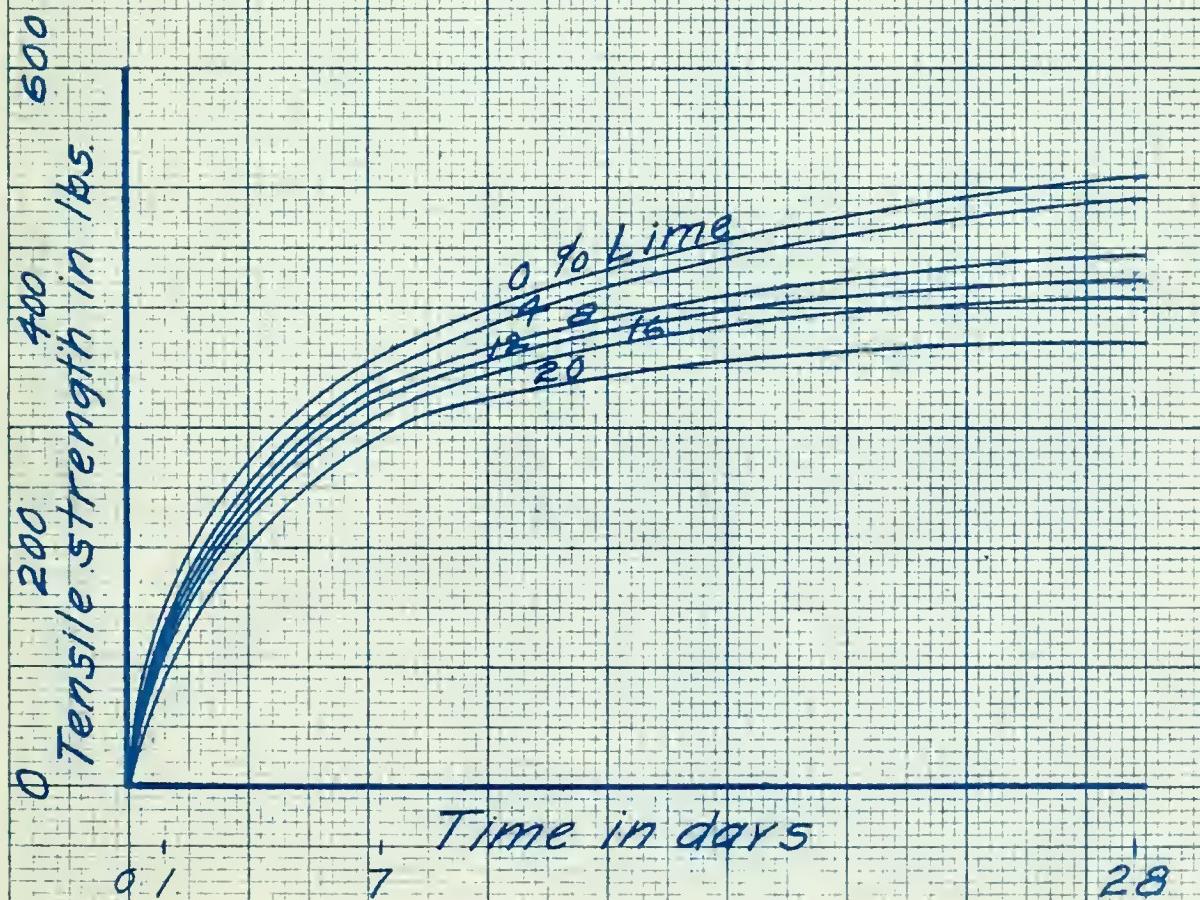


PLATE 12
Neat-tension tests



FREEMAN AND SNOW

PLATE 13
1:2 - tension tests



FREEMAN AND SNOW

PLATE 14
1:3-tension tests

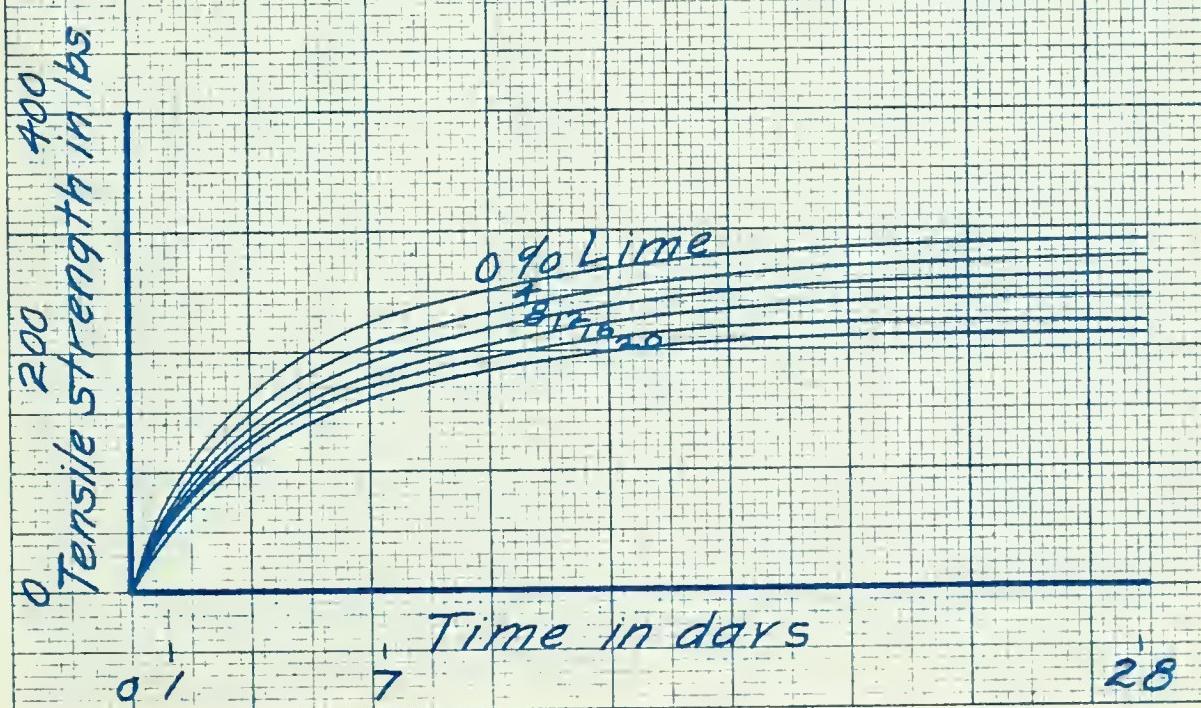


PLATE 15
Neat-Compression tests

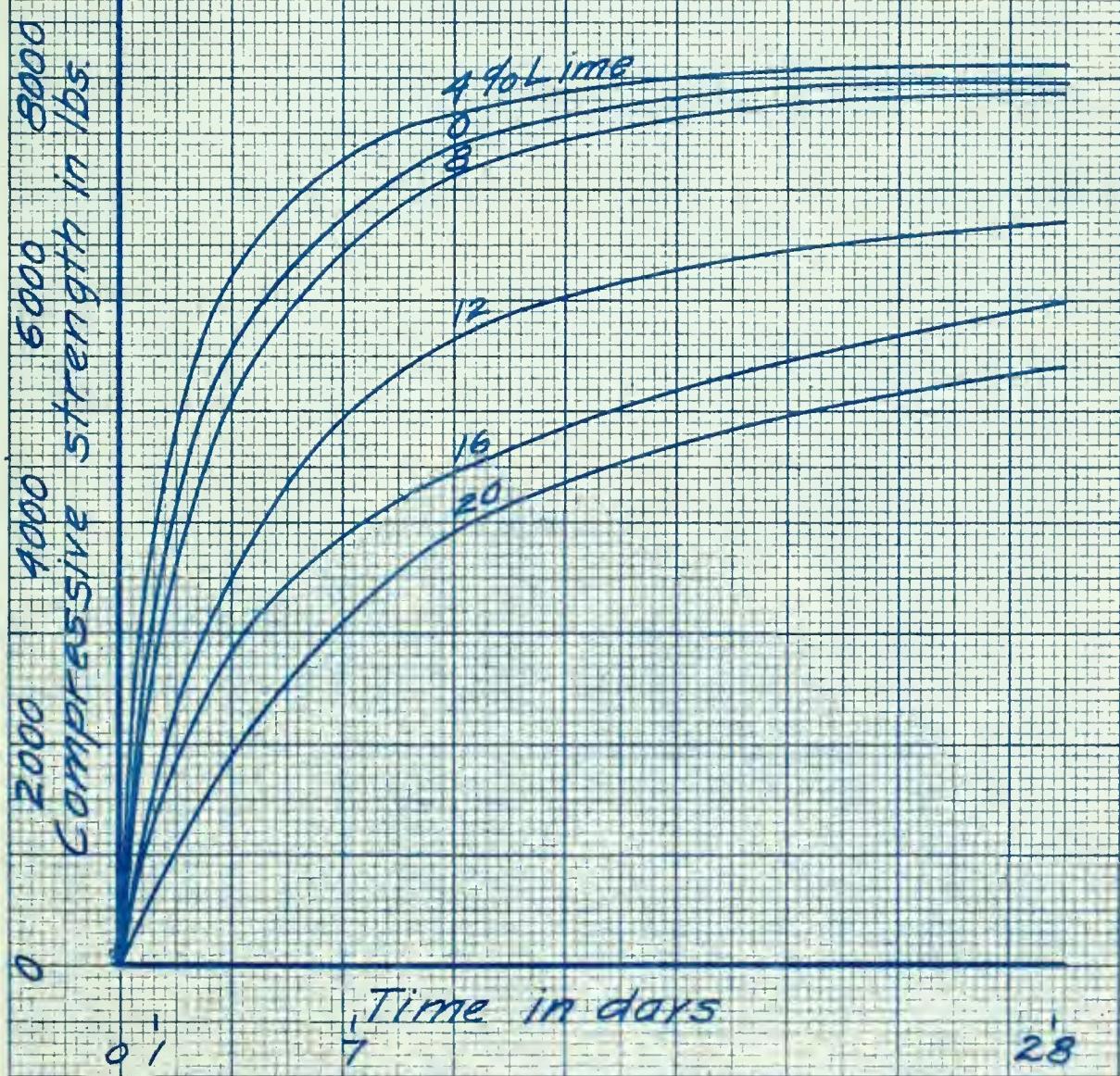
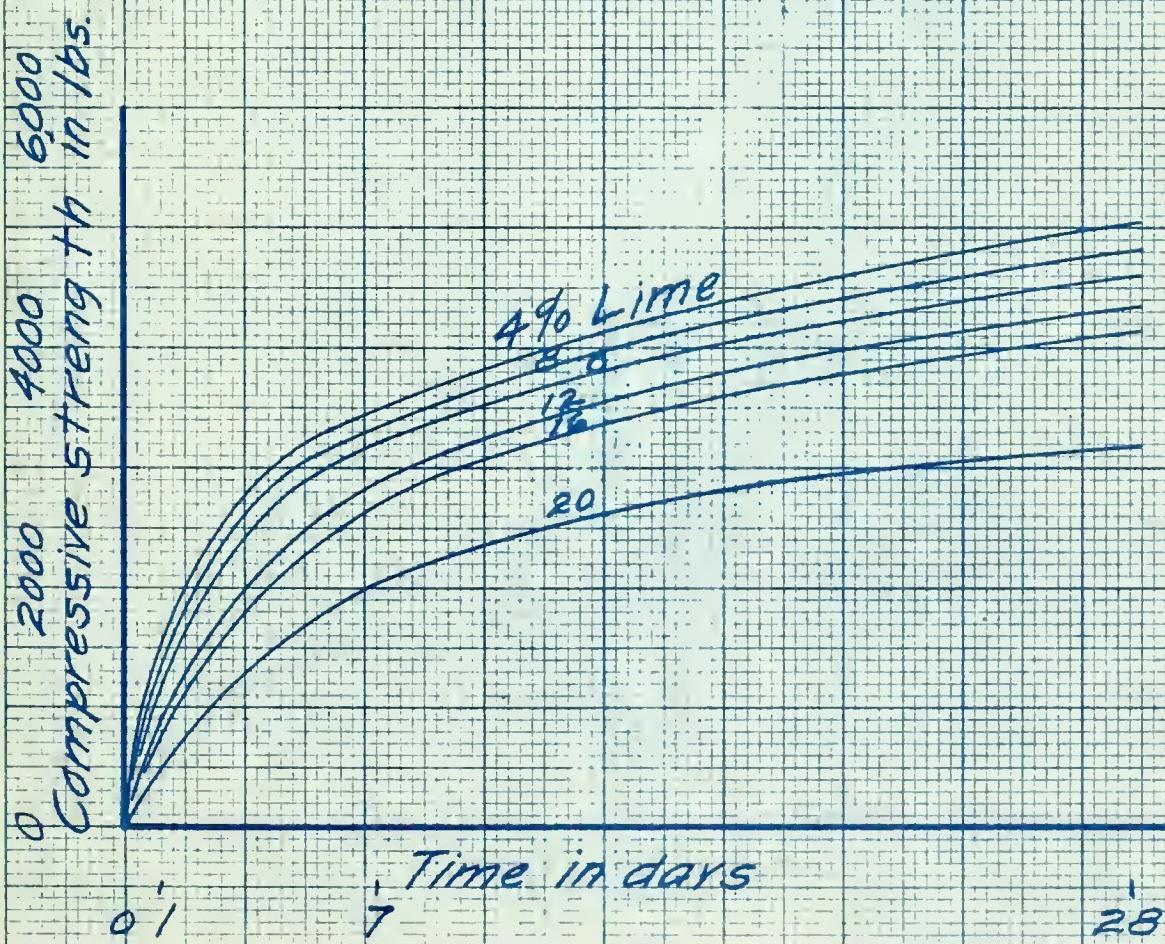


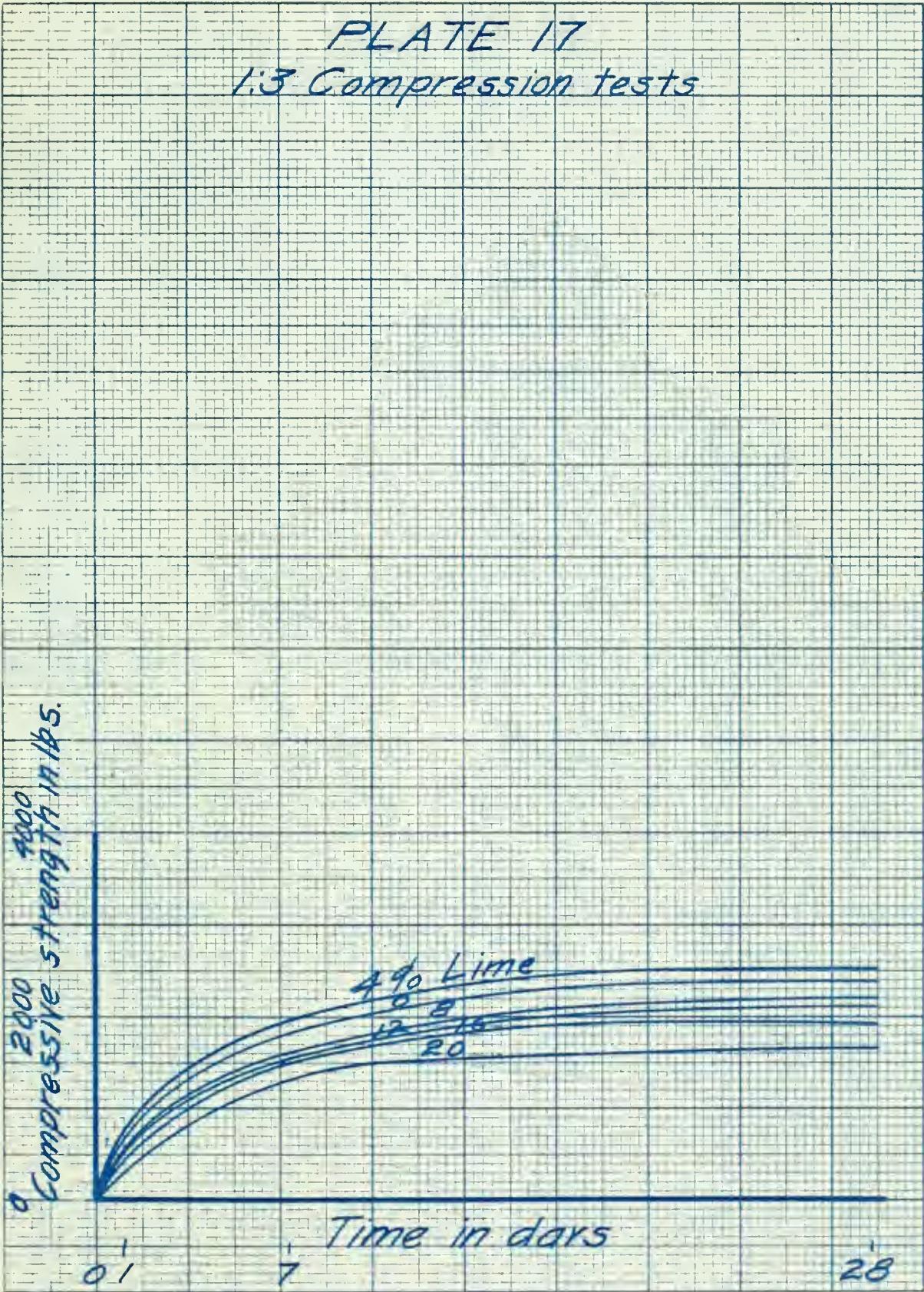
PLATE 16
1.2 - Compression tests



FREEMAN AND SNOW

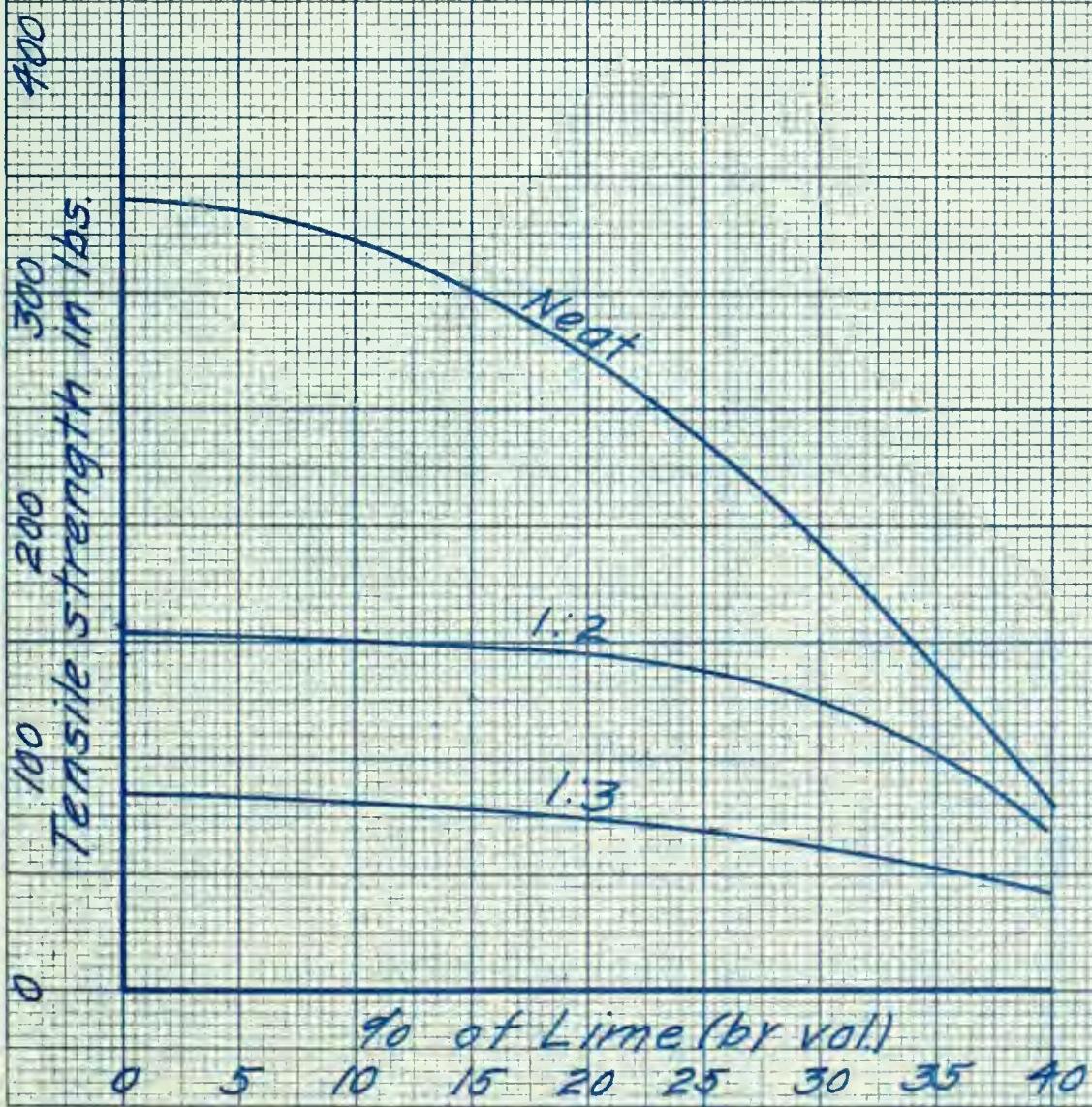
PLATE 17
1:3 Compression tests

Compressive strength 11/18.5.

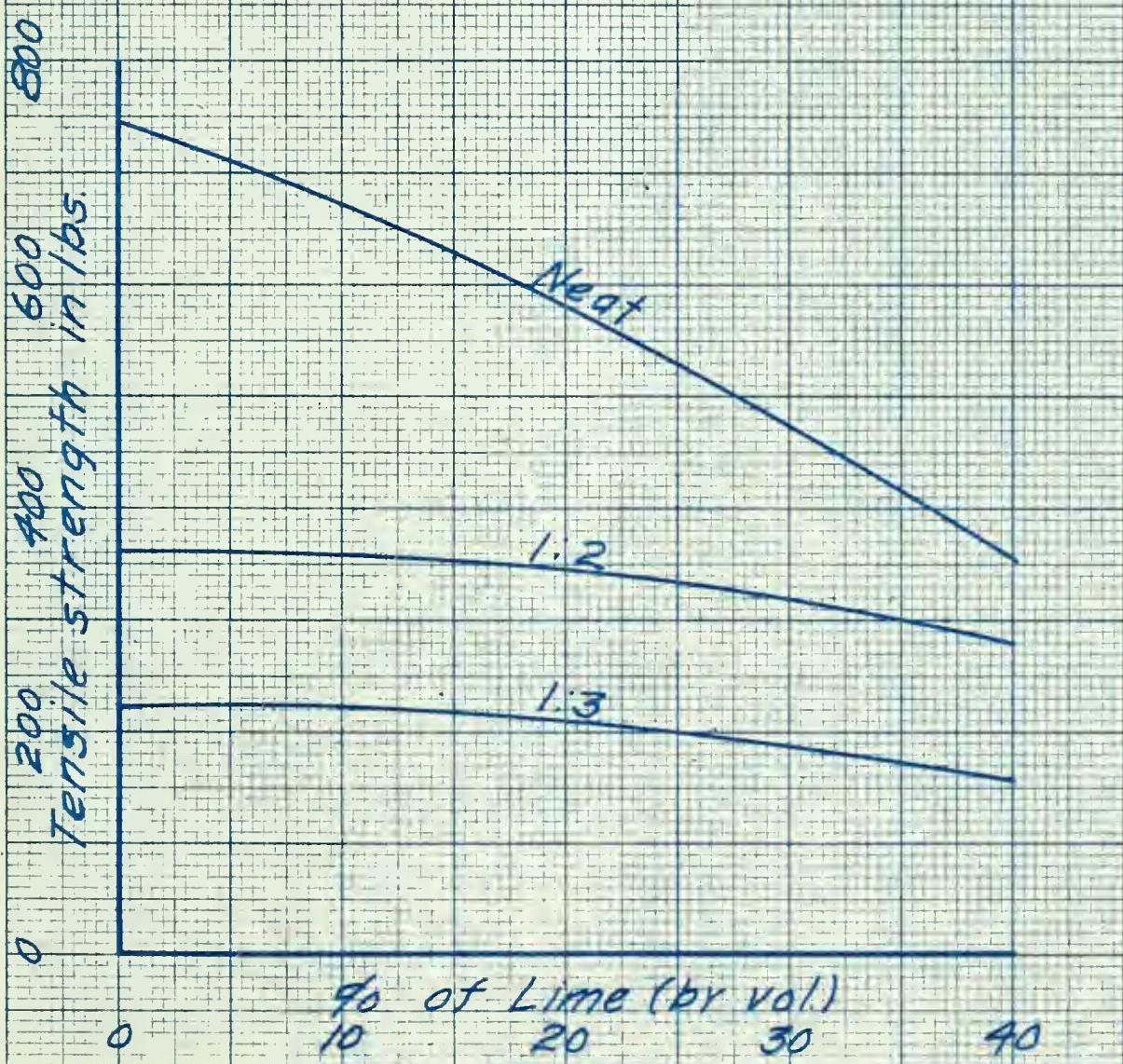


FREEMAN AND SNOW

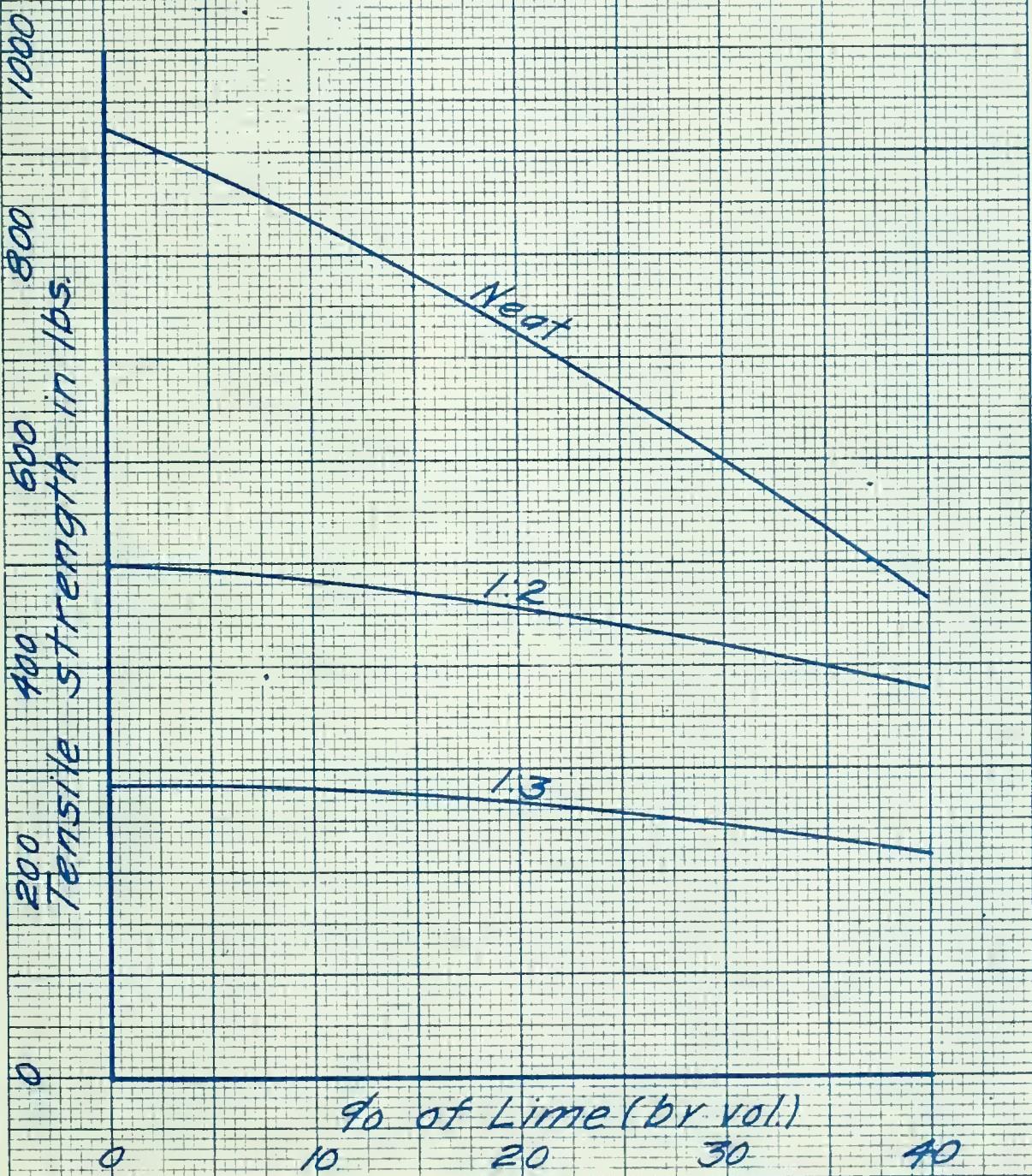
PLATE 18
One day tests



FREEMAN AND SNOW

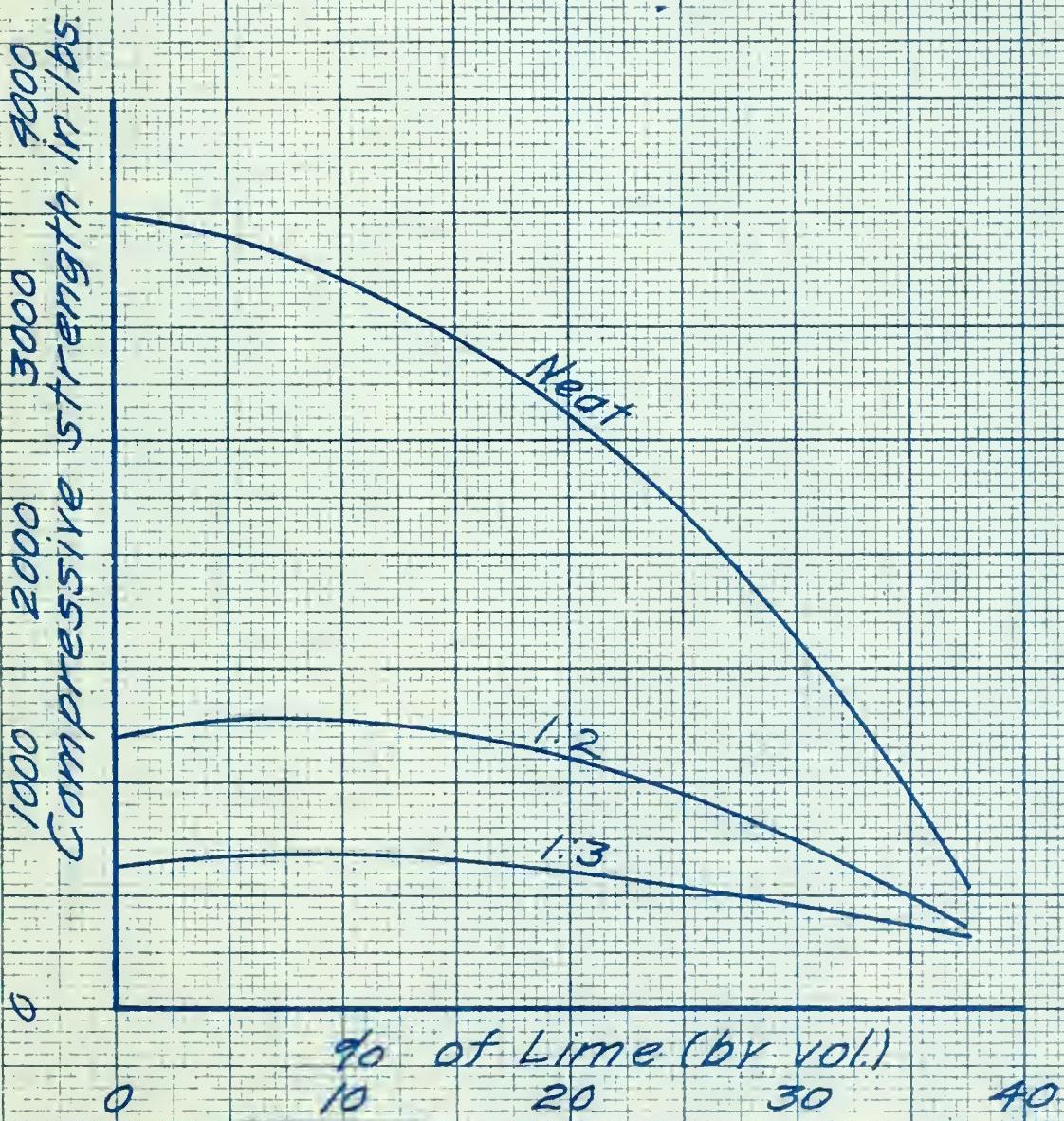
PLATE 19
7 day tests

FREEMAN AND SNOOK

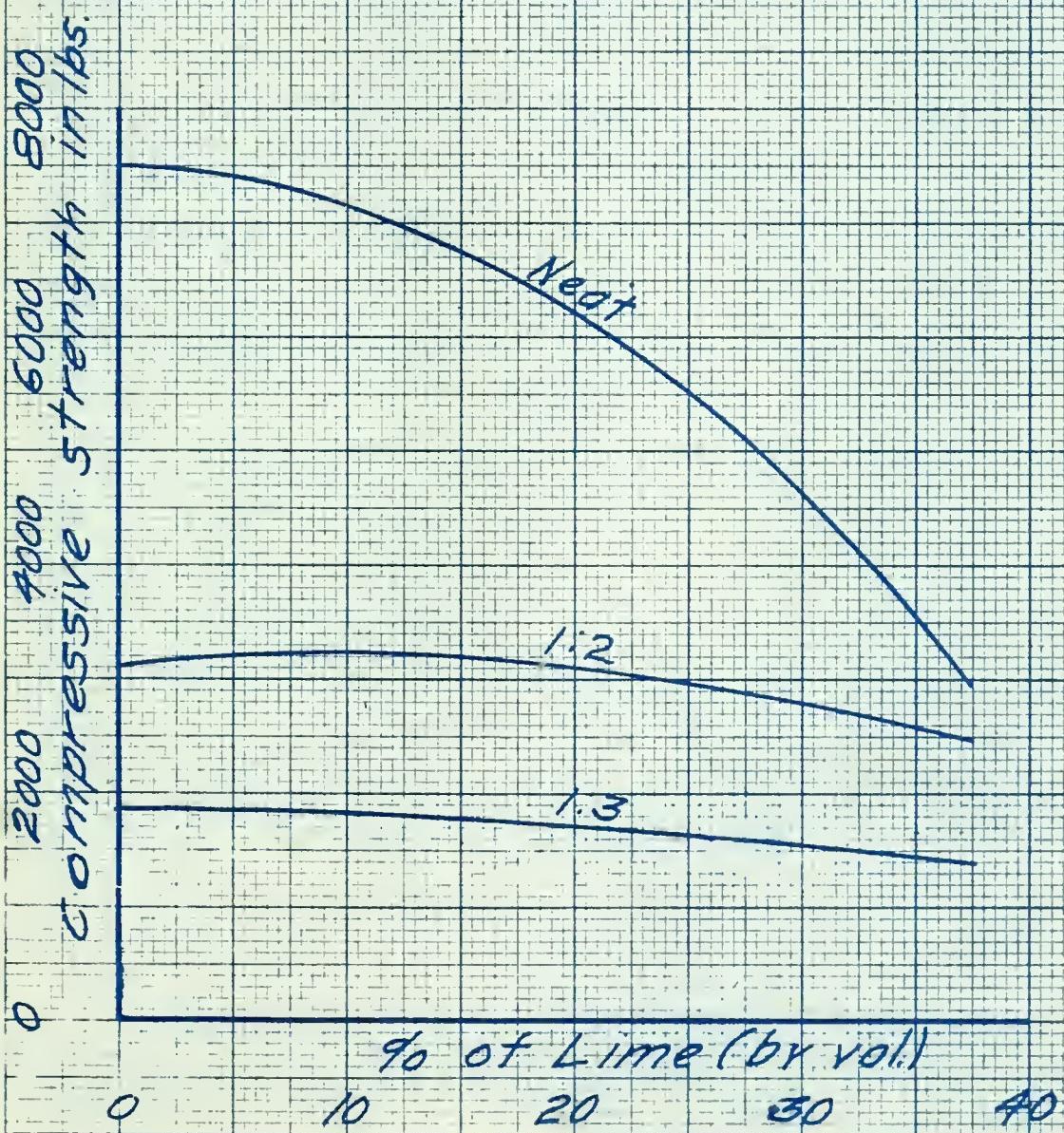
PLATE 20
28 day tests

FREEMAN AND SNOOK

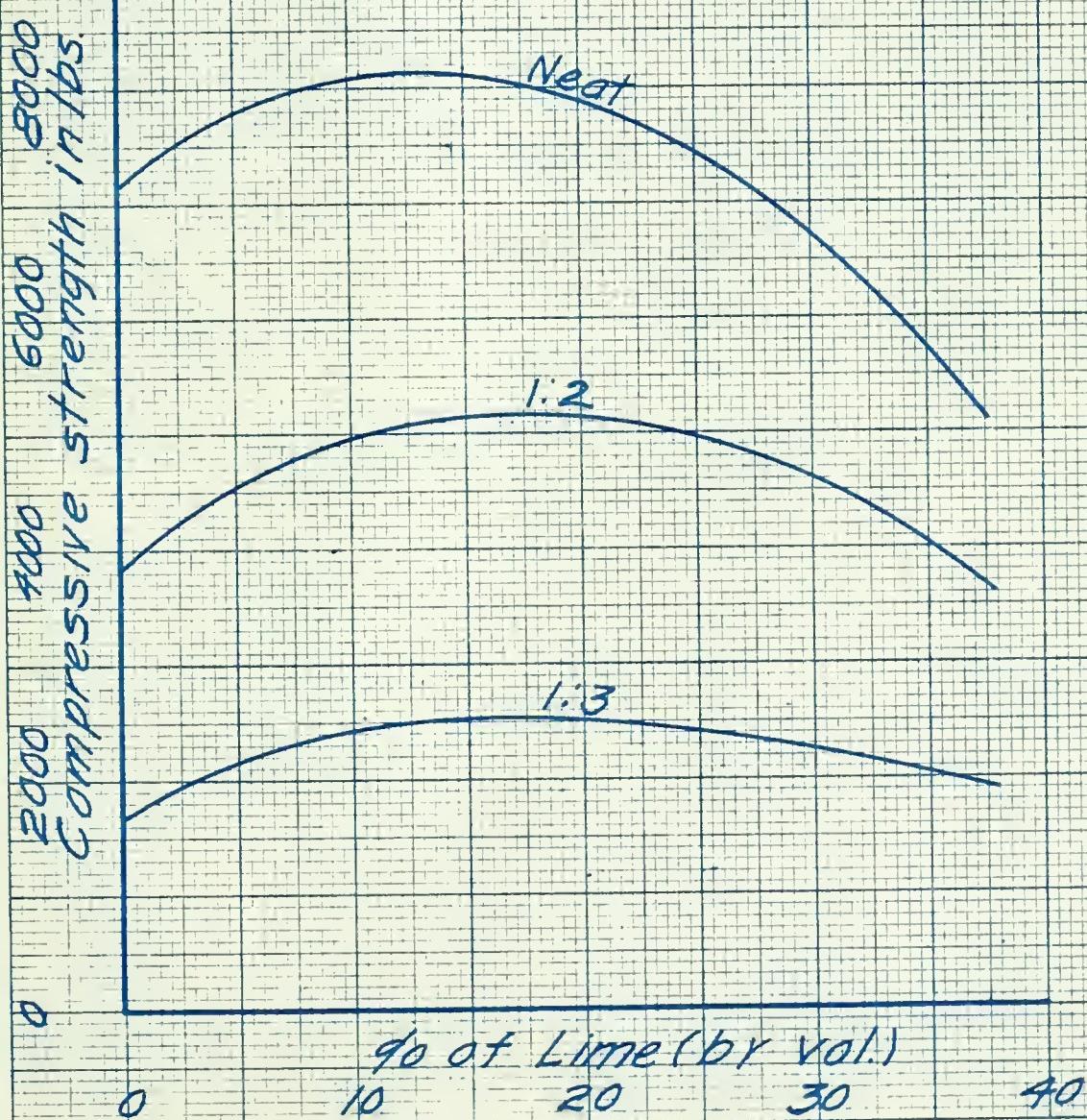
PLATE 21
One day tests



FREEMAN AND SNOOK

PLATE 22
7 day tests

FREEMAN AND SNOW

PLATE 23
28 day tests



PART 2

LABORATORY DATA

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION
OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

Neat Cement Paste

MIX A

0

% Lime

Normal Consistency 24 %

Mixed February 3, 1915

Time of Set: Initial 3-15 hrs. Final: 4-15 hrs.
60 60

No	Hr. Mixed	Tested Date	Hr. By	Tensile Stress Briquette	Comp. Stress Cube	Average	Remarks
1	12:30	2/4/15	1:15 H	350			
2				271	341		
3				402			
4			K		3402		
5					3495	3511	
6					3620		
7		2/10/15	H	763			
8				684	745		
9				788			
10			K		5925		
11					7978	7488	
12					8562		
13		3/3/15	H	956			
14				Flaw	923		
15				891			
16			K		5715		
17					5440	5660	
18					5820		
19		5/11/15	H	860			
20				834	824		
21				789			
22			K		9500		
23					1080	9617	
24					8270		
25							
26							
27							
28							
29							
30							
31							
32							

PAT

No	Test	Remarks
1	Normal in air	OK
2	Normal in water	OK
3	Accelerated	OK

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION
OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

Neat Cement Paste

MIX K

4

% Lime

Normal Consistency 26 $\frac{1}{2}$ %

Mixed March 24, 1915

Time of Set: Initial 3-15 hrs. Final: 4-25 hrs.
60

No	Hr. Mixed	Tested		Tensile Stress		Comp. Stress		Remarks
		Date	Hr.	By	Briquette	Average	Cube	
1	11:00 3/25/15	1:	H	305				
2				279	280			
3				256				
4			K			2960		
5						2760	2890	
6						2950		
7	3/31/15		H	569				
8				687	599			
9				549				
10			K			7850		
11						6560	7337	
12						7600		
13	4/21/15		H	830				
14				860	836			
15				817				
16			K			8000		
17						8260	8130	
18						Flaw		
19								
20								
21								
22								
23								
24								
25								
26								
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30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION
OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Kneepfer

LABORATORY DATA

Neat Cement Paste

MIX J

6

% Lime

Normal Consistency 26 $\frac{1}{2}$ %

Mixed March 24, 1915

Time of Set: Initial 3-10 hrs.
60 Final: 4-30 hrs.
60

No	Hr. Mixed	Tested		Tensile Stress		Comp. Stress		Remarks
		Date	Hr.	By	Brigquette	Average	Cube	
1	9:15 3/25/15	1:	H	250				
2				380	271			
3				284				
4			K			4080		
5						3750	3915	
6						Flaw		
7	3/31/15		H	621				
8				500	624			
9				750				
10			K			7130		
11						4380	6073	
12						6710		
13	4/21/15		H	750				
14				824	772			
15				743				
16			K			8920		
17						7500	8193	
18						8170		
19								
20								
21								
22								
23								
24								
25								
26								
27								
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29								
30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION
OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

Neat Cement Paste MIX H 8 % Lime
 Normal Consistency 27- % Mixed March 19, 1915
 Time of Set: Initial 3-10 hrs. Final: 4-30 hrs.
60

No	Hr. Mixed	Tested		Tensile Stress		Comp. Stress		Remarks
		Date	Hr.	By	Briquette	Average	Cube	
1	9:30 3/20/15		11	H	350			
2					333	331		
3					311			
4				K			2720	
5							2970	2730
6							2500	
7	3/26/15			H	539			
8					552	530		
9					500			
10				K			8170	
11							7520	8127
12							8690	
13	4/16/15			H	544			
14					540	529		
15					502			
16				K			8130	
17							8040	8085
18							Flaw	
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:



A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION
OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Kneepfer

LABORATORY DATA

<u>Neat</u> Cement	<u>Paste</u>	<u>MIX B</u>	<u>10</u> % Lime
Normal Consistency	27 %		Mixed <u>February 8</u> , 1915
		Time of Set: Initial <u>3-15</u> hrs.	Final: <u>4-35</u> hrs.
		60	60

No	Hr. Mixed	Tested		Tensile Stress		Comp. Stress		Remarks
		Date	Hr.	By	Briquette	Average	Cube	
1	10:30	2/9/15	1:	H	262			
2			15		261	252		
3			.		234			
4				K			1980	
5							1650	1830
6							1860	
7		2/15/15		H	524			
8					585	554		
9					554			
10				K			6647	
11							7538	6475
12							5240	
13		3/8/15		H	691			
14					723	695		
15					672			
16				K			10200	
17							5980	7155
18							5286	
19		5/11/15		H	709			
20					625	656		
21					634			
22				K			5530	
23							5160	5345
24							Flaw	
25								
26								
27								
28								
29								
30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	OK
2	Normal in water	OK
3	Accelerated	OK

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION
OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

Neat Cement Paste

MIX C

12

% Lime

Normal Consistency 30 %

Mixed February 10, 1915

Time of Set: Initial 3-25 60 hrs. Final: 4-45 60 hrs.

No	Hr. Mixed	Tested		Briquette	Tensile Stress Average	Comp. Stress Cube Average	Remarks
1	11:00 2/11/15	1:	H	254			
2			15	255	254		
3				Flaw			
4			K			1160	
5						1540	1513
6						1840	
7	2/17/15		H	540			
8				615	543		
9				474			
10			K			6040	
11						4425	4905
12						4250	
13	3/10/15		H	658			
14				676	640		
15				614			
16			K			4670	
17						7780	6730
18						7740	
19	5/11/15		H	680			
20				624	622		
21				563			
22			K			9260	
23						5300	8230
24						10140	
25							
26							
27							
28							
29							
30							
31							
32							

PAT

No	Test	Remarks
1	Normal in air	OK
2	Normal in water	OK
3	Accelerated	OK

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION
OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

Neat Cement Paste

MIX D

14

% Lime

Normal Consistency 31 %

Mixed February 10 1915

Time of Set: Initial 3-30 hrs. Final: 5 hrs.
60

No	Hr. Mixed	Tested Date	Hr. By	Tensile Stress Briquette	Comp. Stress Cube	Average	Remarks
1	3:00	2/11/15	1: H	190			
2				213	201		
3				200			
4			K		980		
5					840	937	
6					990		
7		2/17/15	H	486			
8				559	510		
9				485			
10			K		4968		
11					4800	4927	
12					5012		
13		3/10/15	H	591			
14				687	595		
15				507			
16			K		6110		
17					7620	6650	
18					6220		
19		5/11/15	H	618			
20				533	586		
21				606			
22			K		10330		
23					9630	9090	
24					7310		
25							
26							
27							
28							
29							
30							
31							
32							

PAT

No	Test	Remarks
1	Normal in air	OK
2	Normal in water	OK
3	Accelerated	OK

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION
OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

Neat Cement Paste

MIX E

16

% Lime

Normal Consistency 33 %

Mixed February 15, 1915

Time of Set: Initial 3-35 hrs. Final: 5-15 hrs.

60

60

No	Hr. Mixed	Tested			Tensile Stress Briquette	Comp. Stress Cube	Remarks
		Date	Hr.	By	Average	Average	
1	10:30	2/16/15	1:	H	175		
2					197	182	
3					173		
4				K		1672	
5						1170	1547
6						1800	
7		2/23/15		H	469		
8					414	449	
9					464		
10				K		3805	
11						3825	3877
12						4000	
13		3/15/15		H	496		
14					555	543	
15					578		
16				K		3860	
17						4850	4390
18						4460	
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							
31							
32							

PAT

No	Test	Remarks
1	Normal in air	OK
2	Normal in water	OK
3	Accelerated	OK

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION
OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

Neat Cement Paste MIX F 18 % Lime
Normal Consistency 34 % Mixed February 17, 1915
Time of Set: Initial 4 hrs. Final: 5-30 60 hrs.

No	Hr. Mixed	Tested		Tensile Stress Brigquette	Average	Comp. Stress		Remarks
		Date	Hr. By			Cube	Average	
1	9:30	2/18/15	1: H	139				
2				152	136			
3				117				
4			K			Flaw		
5						1295	1107	
6						920		
7		2/24/15	H	435				
8				403	414			
9				404				
10			K			3070		
11						4525	3785	
12						3760		
13		3/17/15	H	621				
14				609	596			
15				560				
16			K			5965		
17						6390	5792	
18						5020		
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	Cracks within twenty four hours
2	Normal in water	" " " "
3	Accelerated	" " " "

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION
OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

Neat Cement Paste

MIX G

20

% Lime

Normal Consistency 36 %

Mixed February 17 1915

Time of Set: Initial 4-30 hrs. Final: 6 hrs.
60

No	Hr. Mixed	Tested Date	Hr. By	Tensile Stress Briquette	Average	Comp. Stress Cube	Average	Remarks
1	2:00	2/18/15	1: H	108				
2				115	117			
3				128				
4			K			645		
5						570	608	
6						610		
7		2/24/15	H	428				
8				380	391			
9				364				
10			K			3580		
11						2560	2980	
12						2800		
13		3/17/15	H	479				
14				521	498			
15				495				
16			K			5250		
17						5720	5473	
18						5450		
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	Cracks within twenty four hours
2	Normal in water	" " " "
3	Accelerated	" " " "

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION
OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

1:2 Cement Mortar MIX A1 0 % Lime
Normal Consistency 12 $\frac{1}{2}$ % Mixed February 24, 1915

Time of Set: Initial - - - hrs. Final: - - - hrs.

No	Hr. Mixed	Tested		Tensile Stress		Comp. Stress		Remarks
		Date	Hr. By	Briquette	Average	Cube	Average	
1	9:30 2/25/15	1:	H	140				
2				152	147			
3				149				
4			K			1360		
5						1120	1207	
6						1140		
7	3/3/15		H	344				
8				356	363			
9				390				
10			K			1910		
11						1690	1720	
12						1560		
13	3/24/15		H	495				
14				527	504			
15				490				
16			K			3710		
17						3540	3880	
18						4390		
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION
OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Kneepfer

LABORATORY DATA

MIX K1

4

% Lime

1:2 Cement Mortar

Normal Consistency 11.9 %

Mixed March 29, 1915

Time of Set: Initial _____ hrs. Final: _____ hrs.

No	Hr. Mixed	Tested		Tensile Stress		Comp. Stress		Remarks
		Date	Hr. By	Briquette	Average	Cube	Average	
1	10:30 3/30/15		H	151				
2				143	156			
3				175				
4			K			1460		
5						1360	1480	
6						1620		
7	4/6/15		H	453				
8				383	404			Eight day test
9				375				
10			K			3530		Eight day test
11						3250		
12						3500		
13	4/26/15		H	482				
14				490	493			
15				507				
16			K			4450		
17						5080	4943	
18						5300		
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION
OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Kneepfer

LABORATORY DATA

1:2 Cement Mortar

MIX J1

6

% Lime

Normal Consistency 11.9 %

Mixed March 26, 1915

Time of Set: Initial _____ hrs. Final: _____ hrs.

No	Hr. Mixed	Tested		Tensile Stress		Comp. Stress		Remarks
		Date	Hr. By	Briquette	Average	Cube	Average	
1	10:30	3/27/15	11 H	146				
2				105	127			
3				130				
4			K			720		
5						800	750	
6						730		
7		4/3/15	H	322				
8				300	311			Eight day test
9				Flaw				
10			K			2350		
11						2380	2453	Eight day test
12						2630		
13		4/23/15	H	371				
14				370	324			
15				232				
16			K			4160		
17						2820	3250	
18						2770		
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION
OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Kneepfer

LABORATORY DATA

1:2 Cement Mortar

MIX H1

8

% Lime

Normal Consistency 12 %

Mixed March 26, 1915

Time of Set: Initial _____ hrs. Final: _____ hrs.

No	Hr. Mixed	Tested		Tensile Stress		Comp. Stress		Remarks
		Date	Hr. By	Brigquette	Average	Cube	Average	
1	9:00	3/27/15	H	164				
2				157	160			
3				Flaw				
4			K			840		
5						1020	930	
6						Flaw		
7		4/3/15	H	377				
8				412	410			Eight day test
9				440				
10			K			3010		
11						2460	2877	Eight day test
12						3160		
13		4/23/15	H	440				
14				413	429			
15				433				
16			K			3270		
17						2760	3015	
18						Flaw		
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION
OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

MIX Bl

10

% Lime

1:2 Cement Mortar
Normal Consistency 14 %

Mixed February 24, 1915

Time of Set: Initial - - - hrs. Final: - - - hrs.

No	Hr. Mixed	Tested		Tensile Stress		Comp. Stress		Remarks
		Date	Hr.	By	Briguette	Average	Cube	
1	12:45 2/25/15		1:	H	95			
2					107	102		
3					105			
4				K			740	
5							640	733
6							820	
7		3/3/15		H	313			
8					286	300		
9					300			
10				K			2705	
11							2350	2405
12							2160	
13		3/24/15		H	427			
14					470	439		
15					421			
16				K			5610	
17							5070	5320
18							5280	
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION
OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Kneepfer

LABORATORY DATA

1:2 Cement Mortar

MIX C1

12

% Lime

Normal Consistency 12 $\frac{1}{2}$ %

Mixed February 26, 1915

Time of Set: Initial _____ hrs. Final: _____ hrs.

No	Hr. Mixed	Tested		Tensile Stress		Comp. Stress		Remarks
		Date	Hr. By	Briquette	Average	Cube	Average	
1	10:30	2/27/15	11 H	144				
2				146	143			
3				139				
4			K			730		
5						740	733	
6						730		
7		3/8/15	H	410				
8				460	418			Ten day test
9				385				
10			K			2620		
11						3545	3155	Ten day test
12						3300		
13		3/26/15	H	368				
14				436	409			
15				425				
16			K			5890		
17						5540	5543	
18						5200		
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION
OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

1:2 Cement Mortar

MIX D1

14

% Lime

Normal Consistency 13.8 %

Mixed March 1

, 1915

Time of Set: Initial _____ hrs. Final: _____ hrs.

No	Hr. Mixed	Tested		Tensile Stress		Comp. Stress		Remarks
		Date	Hr. By	Briquette	Average	Cube	Average	
1	9:30	3/2/15	1: H	130				
2				176	153			
3				134				
4			K			870		
5						1020	983	
6						1060		
7		3/8/15	H	335				
8				336	327			
9				312				
10			K			3040		
11						3288	3309	
12						3600		
13		3/29/15	H	505				
14				392	451			
15				456				
16			K			3960		
17						5050	4253	
18						3750		
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION
OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

1:2 Cement Mortar

MIX El

16

% Lime

Normal Consistency 14.3 %

Mixed March 3,

1915

Time of Set: Initial _____ hrs. Final: _____ hrs.

No	Hr. Mixed	Tested		Tensile Stress		Comp. Stress		Remarks
		Date	Hr. By	Briquette	Average	Cube	Average	
1	9:30	3/4/15	H	130				
2				120	123			
3				120				
4			K			710		
5						810	757	
6						750		
7		3/10/15	H	304				
8				334	319			
9				319				
10			K			3460		
11						3120	3183	
12						2970		
13		3/31/15	H	383				
14				422	413			
15				432				
16			K			3620		
17						4540	4090	
18						4110		
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION
OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

1:2 Cement Mortar MIX F1 18 % Lime
Normal Consistency 14.5 % Mixed March 3, 1915
Time of Set: Initial _____ hrs. Final: _____ hrs.

No	Hr. Mixed	Tested		Tensile Stress		Comp. Stress		Remarks
		Date	Hr. By	Briquette	Average	Cube	Average	
1	12:15	3/4/15	1: H	126				
2				100	118			
3				Flaw				
4			K			820		
5						860	777	
6						650		
7		3/10/15	H	325				
8				337	321			
9				302				
10			K			3180		
11						2790	2863	
12						2620		
13		3/31/15	H	401				
14				441	425			
15				433				
16			K			4040		
17						4590	4917	
18						5120		
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION
OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

1:2 Cement Mortar

MIX G1

20

% Lime

Normal Consistency 14.8 %

Mixed March 5

, 1915

Time of Set: Initial _____ hrs. Final: _____ hrs.

No	Hr. Mixed	Tested		Tensile Stress		Comp. Stress		Remarks
		Date	Hr. By	Briquette	Average	Cube	Average	
1	10:30	3/6/15	H	85				
2				100	91			
3				89				
4			K			540		
5						460	490	
6						470		
7		3/12/15	H	296				
8				301	299			
9				299				
10			K			2145		
11						2500	2088	
12						1620		
13		4/3/15	H	349				
14				397	371			
15				367				
16			K			2840		
17						3610	3130	
18						2950		
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

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LABORATORY DATA

1:3 Cement Mortar

MIX A2

0

% Lime

Normal Consistency 10 %

Mixed March 10, 1915

Time of Set: Initial _____ hrs. Final: _____ hrs.

No	Hr. Mixed	Tested		Tensile Stress		Comp. Stress		Remarks
		Date	Hr.	By	Briquette	Average	Cube	
1	9:30	3/11/15	11	H	74			
2					97	85		
3					85			
4				K			640	
5							560	630
6							690	
7		3/17/15		H	215			
8					200	225		
9					260			
10				K			2110	
11							1875	1862
12							1600	
13		4/8/15		H	310			
14					284	286		29 day
15					263			test
16				K			1390	
17							1490	1690
18							2190	29 day
19								test
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION
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LABORATORY DATA

MIX K2

1:3 Cement Mortar

4 % Lime

Normal Consistency 10.3 %

Mixed March 31, 1915

Time of Set: Initial _____ hrs. Final: _____ hrs.

No	Hr. Mixed	Tested		Tensile Stress		Comp. Stress		Remarks
		Date	Hr. By	Briquette	Average	Cube	Average	
1	11:30	4/1/15	H	71				
2				80	79			
3				85				
4			K			670		
5						720	617	
6						460		
7		4/8/15	H	266				
8				240	254			Eight day test
9				255				
10			K			1510		
11						1570	1807	Eight day test
12						2340		
13		4/28/15	H	305				
14				384	345			
15				Flaw				
16			K			2130		
17						3170	2537	
18						2310		
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

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LABORATORY DATA

1:3 Cement Mortar

MIX J2

6 % Lime

Normal Consistency 10.4 %

Mixed March 31, 1915

Time of Set: Initial _____ hrs. Final: _____ hrs.

No	Hr. Mixed	Tested		Tensile Stress		Comp. Stress		Remarks
		Date	Hr.	By	Briquette	Average	Cube	Average
1	10:30	4/1/15	11	H	79			
2					57	63		
3					53			
4				K			660	
5							640	677
6							830	
7		4/8/15		H	242			
8					205	225		
9					229			Eight day test
10				K			1610	
11							1250	
12							1580	Eight day test
13		4/28/15		H	298			
14					284	290		
15					287			
16				K			2090	
17							2450	2323
18							2430	
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

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LABORATORY DATA

1:3 Cement Mortar

MIX H2

8

% Lime

Normal Consistency 10.5 %

Mixed March 29

, 1915

Time of Set: Initial _____ hrs. Final: _____ hrs.

No	Hr. Mixed	Tested		Tensile Stress		Comp. Stress		Remarks
		Date	Hr. By	Briquette	Average	Cube	Average	
1	11:30 3/30/15	11	H	69				
2				55	60			
3				57				
4			K			520		
5						630	567	
6						550		
7	4/6/15		H	223				
8				156	204			
9				233				Eight day test
10			K			1590		
11						1500	1623	Eight day
12						1780		test
13	4/26/15		H	233				
14				269	260			
15				279				
16			K			1710		
17						1500	1907	
18						2510		
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

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LABORATORY DATA

MIX B2

10

% Lime

1:3 Cement Mortar
Normal Consistency 10.5 %

Mixed March 8, 1915

Time of Set: Initial _____ hrs. Final: _____ hrs.

No	Hr. Mixed	Tested		Tensile Stress		Comp. Stress		Remarks
		Date	Hr. By	Brigquette	Average	Cube	Average	
1	9:30	3/9/15	1: H	78				
2				64	74			
3				81				
4			K			560		
5						5.80	543	
6						500		
7		3/15/15	H	227				
8				226	225			
9				222				
10			K			850		
11						1020	880	
12						770		
13		4/6/15	H	290				
14				290	295			
15				305				
16			K			2160		
17						2100	2303	
18						2650		
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

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By
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LABORATORY DATA

1:3 Cement Mortar

MIX C2

12 % Lime

Normal Consistency 11 %

Mixed March 10, 1915

Time of Set: Initial _____ hrs. Final: _____ hrs.

No	Hr. Mixed	Tested		Tensile Stress		Comp. Stress		Remarks
		Date	Hr. By	Briquette	Average	Cube	Average	
1	12:30 3/11/15		H	56				
2				64	60			
3				Flaw				
4			K			350		
5						305	315	
6						290		
7	3/17/15		H	179				
8				160	177			
9				193				
10			K			1670		
11						1660	1593	
12						1450		
13	4/8/15		H	245				
14				219	245			29 day
15				270				test
16			K			1570		
17						2770	2150	29 day
18						2110		test
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

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and
Claude A. Knuepfer

LABORATORY DATA

1:3 Cement Mortar

MIX D2

14 % Lime

Normal Consistency 11.2 %

Mixed March 12, 1915

Time of Set: Initial _____ hrs. Final: _____ hrs.

No	Hr. Mixed	Tested		Tensile Stress		Comp. Stress		Remarks
		Date	Hr. By	Briquette	Average	Cube	Average	
1	10:30 3/13/15	11	H	84				
2				78	81			
3				Flaw				
4			K			570		
5						560	557	
6						540		
7	3/19/15		H	198				
8				163	187			
9				181				
10			K			1530		
11						1450	1397	
12						1210		
13	4/9/15		H	248				
14				252	251			
15				254				
16			K			2370		
17						3120	2630	
18						2400		
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

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LABORATORY DATA

MIX E2

16

% Lime

1:3 Cement Mortar
Normal Consistency 11.5 %

Mixed March 15, 1915

Time of Set: Initial _____ hrs. Final: _____ hrs.

No	Hr. Mixed	Tested		Tensile Stress		Comp. Stress		Remarks
		Date	Hr.	By	Briquette	Average	Cube	
1	9:30	3/16/15	11	H	70			
2					82	69		
3					56			
4				K			540	
5							500	507
6							480	
7		3/22/15		H	188			
8					180	179		
9					168			
10				K			1580	
11							1712	1577
12							1440	
13		4/12/15		H	182			
14					212	218		
15					261			
16				K			1340	
17							2130	1710
18							1660	
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

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By
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LABORATORY DATA

MIX F2

18

% Lime

1:3 Cement Mortar
Normal Consistency 11.7 %

Mixed March 17, 1915

Time of Set: Initial _____ hrs. Final: _____ hrs.

No	Hr. Mixed	Tested		Tensile Stress		Comp. Stress		Remarks
		Date	Hr.	By	Briquette	Average	Cube	
1	9:30	3/18/15	11	H	82			
2					68	74		
3					71			
4				K			520	
5							380	433
6							400	
7		3/24/15		H	220			
8					193	201		
9					189			
10				K			1720	
11							1780	1693
12							1580	
13		4/15/15		H	247			
14					303	277		29 day test
15					282			
16				K			3500	
17							2500	2673
18							2020	29 day test
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

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LABORATORY DATA

1:3 Cement Mortar

MIX G2

20

% Lime

Normal Consistency 12 %

Mixed March 17, 1915

Time of Set: Initial _____ hrs. Final: _____ hrs.

No	Hr. Mixed	Tested		Tensile Stress		Comp. Stress		Remarks
		Date	Hr. By	Briquette	Average	Cube	Average	
1	12:30 3/18/15	11	H	40				
2				48	44			
3				Flaw				
4			K			310		
5						260	277	
6						260		
7	3/24/15		H	164				
8				183	169			
9				149				
10			K			1220		
11						1450	1400	
12						1530		
13	4/15/15		H	206				
14				228	210			29 day
15				197				test
16			K			1880		
17						1930	1933	29 day
18						1990		test
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:



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